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GREEN HYDROGEN IN URUGUAY: AN ANALYSIS OF ITS IMPACT ON NATIONAL LOGISTICS

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Felipe Lavega[1], Otacilio José Moreira[2], Américo da Costa Ramos Filho[3] and Maria Carolina Rodrigues[4].

ABSTRACT

The objective of this article is to analyze the actuality of "Green Hydrogen" produced from water electrolysis, with the use of energy generated from renewable sources (wind and/or photovoltaic). In Uruguay, and its impact on Logistics from the socioeconomic and infrastructure challenges to production, storage, distribution and export. Since Uruguay has been boosting the development of production and following the objectives set by the decarbonization established worldwide with a change in the energy matrix through renewable energies as public policies that strengthen this development. The qualitative, explanatory, descriptive method was used, involving bibliographic research and case study, in order to evaluate the results as well as the opinions of the Stakeholders and main actors in the national production. With the case study we can conclude in this article that Green Hydrogen has the potential to have a significant impact on logistics: From reducing carbon emissions in freight transport to providing a solution for the storage of renewable energies, helping to make logistics more sustainable and combat climate change. According to the literature review of the "Green Hydrogen Roadmap in Uruguay" and the result of the analysis of the working tables, a great competitive opportunity is seen for Uruguay, which will have a positive impact on National Logistics.

Keywords: Green Hydrogen. Renewable energy. Logistics. Sustainability.

[1] MBA Logemp UFF.
Email: felipe.lavega5@gmail.com
[2] Graduate Program in Administration (PPGAd), Fluminense Federal University – UFF. Guest professor.
E-mail: otaciliomoreira@id.uff.br.
ORCID: 0000-0001-9271-1210
Web of Science ResearcherID - AEQ-8094-2022
[3] DSc., CMQ/OE, CQE
Associate Professor II
Department of Administration – STA
Fluminense Federal University.
E-mail: americoramos@id.uff.br
ORCID iD:https://orcid.org/0000-0003-4643-9767
Web of Science Researcher ID - AAG-5161-2019
[4] DsC University of Algarve (CinTurs).
E-mail: macarolrodrigues@gmail.com
ORCID: https://orcid.org/0000-0003-2575-861

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INTRODUCTION

Green hydrogen, produced from the electrolysis of water using energy generated by renewable sources, such as wind and photovoltaic, has stood out as a promising solution for the decarbonization of the global energy matrix. In Uruguay, where the development of renewable energies is strongly driven by public policies, the production of green hydrogen represents a strategic opportunity to transform national logistics (Castro et al., 2022).

In a world driven by the urgent need to combat climate change, Castro et al. (2022) consider Latin American countries, especially Chile, Colombia, Brazil, and Uruguay, to be very competitive, given their potential for renewable energy production. These countries have already started to develop strategies for the development of low-carbon hydrogen in the long term. Thus, the recent news about Uruguay's commitment to the development and production of green hydrogen positions the country as one of the global leaders in the search for a sustainable and decarbonized future.

Driven by comprehensive national policies aimed at promoting renewable energy, Uruguay is rapidly reducing its reliance on fossil fuels and adopting a cleaner, greener energy landscape. These initiatives establish practices to mitigate environmental degradation, directly impacting the quality of life of the planet's inhabitants (Riaño, 2021). The study by Bouzas, Telíz, and Díaz (2024) explores Uruguay's potential to become a leader in green hydrogen production, considering its significant investment in renewable energy. In addition, the authors point out the challenges and opportunities associated with the deployment of this technology, including infrastructure, storage, and distribution issues.

These energies represent 97% of the Uruguayan energy matrix. According to Ferragut et al. (2022), this percentage reflects the country's internal energy consumption, based on clean sources, such as wind, photovoltaic, hydroelectric, and biomass, positioning Uruguay at the forefront of South America and generating important competitive advantages in the sector.

The cornerstone of this transformation lies in the commercial opportunities and geography of the country. However, it is emphasized that the commitment of the entire national political system, which unanimously supports and promotes the development of clean energy, is of paramount importance. This can be observed in Law No. 16,906, known as the "Investment Law", which promotes and protects foreign investments in the national territory, stimulating the development of millionaire projects in the energy sector. Examples include the "H24U", "Green Hydrogen Hub Drum" and "HIF Global" projects, which will

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allocate 4 billion dollars for the production of green hydrogen and derivatives (Schaich, 2023).

The central question that this article seeks to answer is: How can the production and use of green hydrogen in Uruguay impact national logistics, considering socioeconomic and infrastructure challenges?

This article aims to evaluate the impacts of the Uruguayan green hydrogen project on National Logistics, focusing on the socioeconomic and infrastructure challenges related to the production, storage, distribution and export of this fuel.

The secondary objectives are: to analyze the internal challenges both in relation to the business sector, infrastructure and in relation to society, to determine with those involved in the projects the advantages and disadvantages of the development of green hydrogen projects in Uruguay, confirming the importance of the Government with policies of sustainable commitments set out in the Green Hydrogen Roadmap in Uruguay.

The paper delves into the broader implications of green hydrogen for logistics, shedding light on the profound impact it can have on sustainable and environmentally friendly supply chains. As the world grapples with the urgent need to reduce CO2 emissions and curb the effects of greenhouse gases, sustainable logistics practices are more critical than ever.

Green hydrogen, according to Kramer et al (2006), has the potential to replace fossil fuels as a primary source of energy in several sectors; above all, for the logistics sector, promising a cleaner and more efficient way to transport goods and services. Through this article, we will examine the competitive advantages arising from the adoption of sustainable and eco-friendly logistics practices, underpinned by Green Hydrogen. By reducing carbon emissions and mitigating the effects of climate change, Uruguay's pioneering efforts in this domain have the potential to set a transformative example for nations around the world.

In essence, this article seeks to highlight the intrinsic link between sustainable development, environmental preservation, and human prosperity. It strives to show how Uruguay's ambitious foray into Green Hydrogen not only enhances its economic prowess, but also ensures that this newfound prosperity is realized without compromising the needs of future generations. As we navigate the intricate challenges of a changing world, it's up to us to protect our planet, our ecosystem, and the well-being of all inhabitants. Uruguay's journey in Green Hydrogen is not just a chapter in its history; It is a testament to the

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limitless potential of human innovation and a beacon of hope for a more sustainable and equitable world.

The scope of this study includes a detailed analysis of the public policies that drive the development of renewable energies in Uruguay, as well as the potential impacts of green hydrogen on national logistics. The relevance of this topic lies in the ability of green hydrogen to transform logistics, making it more sustainable and contributing to the decarbonization goals established globally.

LITERATURE REVIEW

GREEN LOGISTICS AND SUSTAINABLE DEVELOPMENT

The potential of hydrogen in Logistics stands out through Kramer et al. (2006) and Reda et al. (2024, where the authors discuss the role in increasing energy security and reducing CO2 emissions. The authors suggest that with Carbon Capture and Storage (CCS) in hydrogen production, CO2 emissions from transport could be reduced by 85%, Especially if hydrogen fuel cell vehicles replaced hybrid vehicles with internal combustion engines.

As competition continues to intensify in the business world, for Tuzun Rad et al. (2017), green logistics has become an imperative for companies seeking a competitive advantage. According to them, by adopting and implementing these sustainability-focused strategies, companies not only contribute to environmental preservation, but also improve their brand reputation and cost-effectiveness, positioning themselves as leaders in the era of eco-conscious commerce.

Kumar's (2015) research highlights the vital role of green logistics in achieving sustainability goals within organizations. By integrating environmental considerations into logistics practices, companies can contribute to the tripod of economic, social, and environmental benefits. However, more empirical research and case studies are needed to substantiate these theories and provide actionable insights for companies looking to adopt sustainable logistics practices.

According to the signing of the United Nations Paris Agreement (2016) with the main objective focused on climate change and thus achieving the Sustainable Development Goals as a goal established by the year 2030 (Riaño, 2021) Uruguay has been working along the same lines as a state policy, since the creation of the Ministry of Environment (2020) which was non-existent until that moment, favored and strengthened business and

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social practices in accordance with sustainability, also having its impact on green logistics with the enactment of: *Law 19.655 Sustainable use of plastic bags 2019* obliging factories and importers to use plastic bags allowed by legislation, which must be biodegradable to mitigate the environmental impact as well as other important measures.

The Uruguayan government has expressed its commitment to the transition to a low-carbon economy, promoting investment in renewable energy sources and the development of the following objectives:

a. Promote the conscious use of natural resources, aiming to avoid the depletion and degradation of the environment, reducing greenhouse gas emissions and minimizing the environmental impacts resulting from logistics activities. According to (Riaño-2021) where it says that green logistics is part of an organizational philosophy in which economic, social and environmental factors have a great relevance.
b. Establish sustainable production and consumption practices (Law 19.655), reducing waste and optimizing the use of available resources, promoting the use of renewable energy and the adoption of clean technologies in logistics, aiming to reduce dependence on fossil fuels and reduce environmental pollution. (Green Hydrogen Roadmap in Uruguay-2021)
c. Establish efficient management practices, seeking to minimize transport times, operating costs and environmental impacts and promoting the training and awareness of professionals involved in logistics, aiming at the adoption of sustainable practices, this awareness should not be limited to professionals working in the logistics sector but according to the speech of the President of the European Council Charles Michel, (CP26, UN Conference 2021) on Climate Change, where he expressed the following: "human beings have declared war on nature and it is up to us to put an end to it. Planet earth is our only place to live, the time has come to act and act together" This appreciation of the words mentioned above is the greatest challenge that nations will face.

These objectives aim to develop logistics in a sustainable way, minimizing environmental and social impacts and contributing to the preservation of the environment and to the improvement of people's quality of life, using a phrase that accompanies the author over time that logistics begins with people and the promotion of public policies

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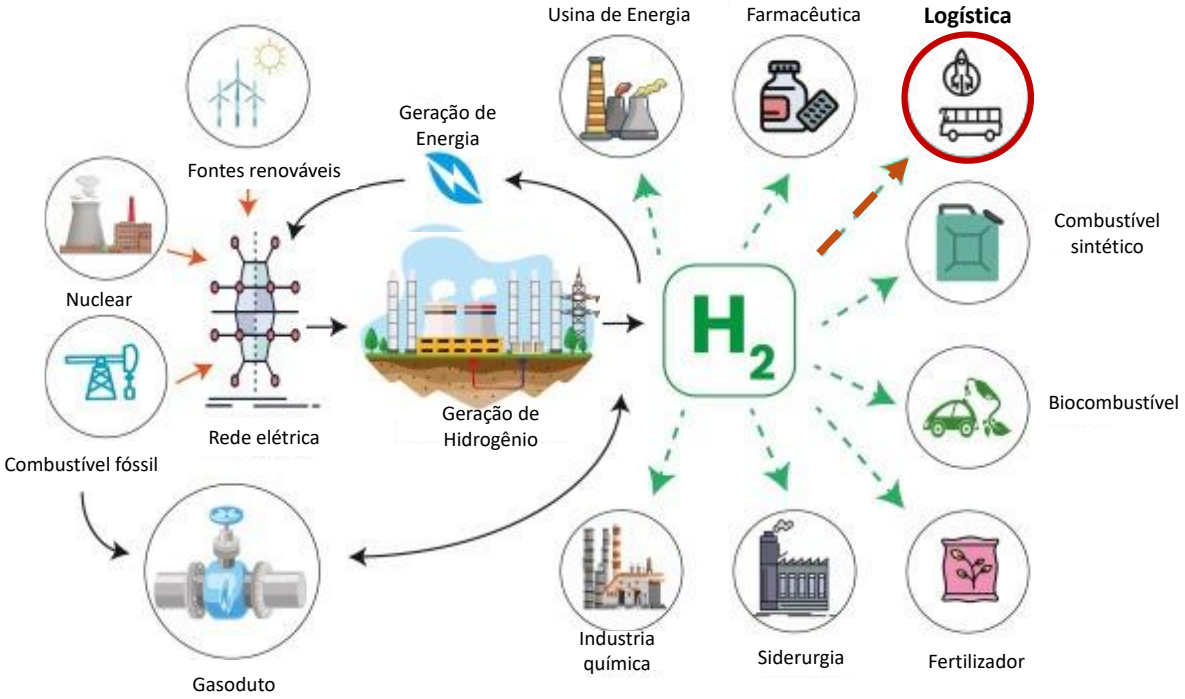
according to sustainability is useless if we as a society continue with practices that are harmful to the environment environment.

THE GREEN H2 VALUE CHAIN

The green hydrogen value chain is defined by Reda et al (2024) as the process that integrates the production of hydrogen using renewable energy sources to its distribution, storage, and end-use applications. This value chain is essential for achieving sustainability and reducing greenhouse gas emissions and includes the production, transportation, storage, and utilization of green hydrogen. (Figure 1)

Figure 1- The Green Hydrogen Supply Chain



Source: Adapted by the authors

The figure contemplates the sources of generation and various applications, we emphasize, in particular, the use in logistics, which is the subject of the study.

The study by Donato (2022), found a positive relationship between the factors that contribute to supply chain resilience and its performance that results in significant benefits for the business, including the ability to react quickly to challenges, overcome risks, and face disruptions in operations.

For Donato, Supply Chain Resilience (CSR) is a logistics model that demonstrates its effectiveness in dealing with Green Hydrogen (H2V) through its ability to identify and

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respond promptly to vulnerabilities and possible disruptions in product flows, ensuring its continuity and efficiency.

However, the author points out that this research has faced limitations, including the scarcity of academic material that addresses cases of resilient green supply chains and Green Hydrogen-related chains. This indicates the need for further investigation in these domains to deepen our understanding of these growing topics.

The study conducted by Masip et al (2021), provides a comprehensive overview of the green hydrogen (H2) value chain within port facilities in the Valparaíso region of Chile. It encompasses several elements, specific to the type of installation; such as, electricity generation through solar PV and inverters, electrolyzers for H2 production, on-site storage, and fuel cells.

The research identified potential consumers of green H2 within the port facility, such as RTG cranes, forklifts, manlifts, container handlers, container reach forklifts, yard tractors and crawler conveyors, many of which currently rely on diesel fuel, demonstrating the attractiveness of transitioning to green H2 in these applications.

According to (Donato 2022) industrially produced hydrogen is classified, by a color code, according to the process, raw material and inputs used:

Table 1 Classification of Green Hydrogen

Code of cores	Raw material	Process	Input
Purple	Water	Nuclear energy	Electrolysis
Turquoise	Natural gas	Pyrolysis	-
Brown and black	Coal	Gasification	-
Grey	Fossils	Steam refurbishment	-
Blue	Natural gas	Gasification	CO2 Capture
Moss	Biomass	Decomposition	-
Green	Water	Electrolysis	Renewable energy

Green hydrogen, the object of study in this article, should only be considered 100% green if it is inserted in a green supply chain, which is composed of the supply stage (raw material), energy generation (renewable sources - solar, wind or hydraulic) and distribution, it is essential that all members who are involved in the processes of the chain, work more efficiently in order to generate less impact on the environment Salmon et al (2021).

The green hydrogen value chain is a way to integrate renewable energies and help in the transition to a more sustainable and low-carbon energy system.

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THE PREPARATION OF THE GREEN H2 ECONOMY AND ITS CHALLENGES

When addressing the subject, Ferragut et al (2022) establish the following challenges:

Table 2 - Preparing the economy

Preparing the economy	Action Required
Long-term vision that transcends periods of government.	Development of new policies such as the 2005-2030 energy policy.
Comprehensive regulations (norms and standards)	Ensuring the safety of operations related to green hydrogen.
Encouragement of foreign investment (projects, technology transfer, etc.)	Maintain stable rules and favorable access to financing, keeping the country attractive for investments in this sector.
Strategic infrastructure planning	Enable the production, transportation, storage, and distribution of green hydrogen.
International cooperation	Stimulate the exchange of knowledge, the development of capacities and the exploitation of opportunities for regional integration.
Governance and communication strategy	Achieve social consensus and gain greater acceptance of green hydrogen by engaging actors and building a solid support base
Planning and execution of training and research and development (R&D) programs,	Develop local capacities, both in technical and construction terms, including engineers and specialists

Source: Ferraguti 2020

Green Hydrogen means great opportunities for Uruguay in the present and future, bearing in mind the advance of renewable energies around the world, but it also has many challenges ahead, such as the need for a social and political consensus for the project to be prosperous and to be an example for other countries that are traveling this path of the path. (Table 3)

Table 3: Challenges and actions

Challenge	Short-term action	Long-term action
Infrastructure development	Construction of new production facilities, such as renewable energy farms and electrolyzers, as well as infrastructure for hydrogen transportation and storage	Detailed engineering of pipelines, transport lines and port infrastructure (currently non-existent because Uruguay concentrates activities in its cargo terminals in containers and grains.
Cost reduction	Reduce production costs through process optimization and the development of more efficient technologies	Improving the efficiency of electrolyzers, reducing renewable energy costs or developing more efficient catalysts.
Large-scale production	Building large-scale production facilities and ensuring a steady supply of renewable energy to power hydrogen production.	Develop solutions to store and distribute large quantities; as well as logistics solutions for export, as domestic

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		consumption is very small for the production quantities planned for the medium and long term.
Market acceptance	Invest in educating consumers about the benefits of green hydrogen and demonstrate that it is a viable and sustainable alternative as another form of energy.	Create a favorable regulatory environment with financial incentives to promote the use of green hydrogen in sectors such as transportation, industry, and power generation.
International cooperation	Cross-country collaboration to share knowledge, technologies, and best practices, as well as the coordination of international policies and standards	Develop trade and transport agreements to facilitate trade in green hydrogen between countries. Ex: working chambers in Germany

Source: The authors

Preparing the green hydrogen economy requires significant international cooperation to overcome the challenges. One can highlight the international projects such as the Hydrogen Council, with more than 130 leading companies in the transport and energy industry that seek to increase investments. (DEAGO-DELGADO et al. (2022).

METHODOLOGY

According to Diana (2019) and Vergara (1998), this is a qualitative, explanatory, descriptive research, involving bibliographic research and field interviews, reflecting a comprehensive approach to understanding and analyzing the phenomenon under study. It is a qualitative research, considering that it aims to understand phenomena, studies of particularities and individual experiences.

CASE STUDY - GREEN HYDROGEN IN URUGUAY

In recent years, Uruguay has been working hard referring to Green Hydrogen driven by the objectives set by the decarbonization established worldwide and reflected in what is called the "green hydrogen roadmap in Uruguay", this being a public document that dealt with the subject at the government level, where different ministries gave their technical contributions with the aim of promoting the development and production of Green Hydrogen and its derivatives in the country, since with the change in the energy matrix through renewable energies, 97% of the energy is consumed in the country. The growth of sustainability as a public policy is very favorable and Logistics follows this development in this aspect, as it contributes from the point of view of improving its processes, preserving human existence and cooperation in respect for the environment

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Green Hydrogen is essential to achieve the decarbonization goals for the reduction of Greenhouse Gases, and its versatility of use is what greatly favors its development, and it can be used directly or in combination with other elements.

We see its application in the logistics sector in land, sea, and air transport, both in the relationship with industry in general and in the domestic environment, strengthening renewable energy systems. It is estimated that Uruguay has great potential for the production of Green Hydrogen, especially in the agro-industrial and logistics sector. The production of this fuel will be able to take advantage of the surplus renewable energy generated at the time of greater agricultural and livestock production, thus avoiding the emission of greenhouse gases.

In addition, Green Hydrogen has applications in sectors such as transportation, power generation, and the chemical industry, which would open up the possibility of diversifying the country's energy matrix and reducing its dependence on fossil fuels. However, it is important to take into account that the development of Green Hydrogen in Uruguay requires significant investments in infrastructure and technology, in support of public policies that promote its adoption.

According to the document called "Green Hydrogen Roadmap in Uruguay", the country began working on the development of green hydrogen in 2018, based on the formation of an initial inter-institutional group formed by the Ministry of Industry, Energy and Mining (MIEM) and the public energy companies ANCAP (Fuels) and UTE (Energy). In this first stage, the development of green hydrogen was understood as a natural step for the country, after the decarbonization of the electricity matrix was completed. The opportunities that would be generated in the medium and long term in the decarbonisation of the energy sector (heavy road, maritime and air transport; industry, etc.) and raw materials are visualised, which adds the advantage of constituting an energy vector that allows the distribution of renewable energy between sectors and regions. The focus of this moment was the analysis of the production of green hydrogen from renewable energies and its use in heavy and long-distance transport, in what was called the "Green Project". In 2020, the interinstitutional hydrogen group was expanded and other ministries and state institutions were incorporated. (Green Hydrogen Roadmap in Uruguay - 2021). The scope of each of them is detailed below:

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Chart 4 - Scope of the working groups

Scope 1	Scope 2	Scope 3
-Supply and demand of green hydrogen and derivatives. -Production costs in Uruguay: levelized cost of electricity (LCOE), levelized cost of hydrogen (LCOH) and cost of hydrogen derivatives. -Potential domestic and export market	-Facilitators and barriers. -Regulatory aspects, licenses, financing, bilateral agreements, necessary infrastructure, talent and social license.	-Initial proposal for a roadmap for green hydrogen, socio-economic benefit, risk analysis. After a process of analysis and exchange with relevant actors at the national and international level, it is concluded that Uruguay has very good conditions for the development of green hydrogen and derivatives, both for local marketing and for export. It is from this conclusion that this roadmap for 2040 is proposed.

Fonte: McKinsey & Company. (2021)

A COUNTRY THAT PROMOTES SUSTAINABLE STRATEGIES

In what is identified as the first stage of its energy transformation, Uruguay has practically achieved the decarbonization of electricity generation. The above translates into an average share of renewable energies in the electricity matrix of 97% in the period between 2017 and 2020 (53% wind, solar and biomass and 44% hydroelectric), although the value varies according to the climatic characteristics of each year. In this way, the country has significantly reduced greenhouse gas emissions from the energy sector. The second stage of the energy transition in Uruguay includes, among other challenges, the decarbonization of the rest of the energy sector (transport and industry), and of raw materials for industrial use, the development of a hydrogen economy, the maintenance of a high share of renewable energies in the electricity matrix, and the more efficient use of the electricity system. (Green Hydrogen Roadmap in Uruguay - 2021)

ENERGY POLICY AND THE FIRST STAGE OF THE TRANSITION

In 2008, Uruguay presented its energy strategy, in which its commitment to renewable energies and energy efficiency is explicit. This policy seeks, on the one hand, to transcend the traditional reductionist vision based on techno-economic analysis, incorporating exclusively the analysis of geopolitical, environmental, social, ethical and cultural dimensions. On the other hand, this public policy promotes long-term thinking and planning. Perhaps its most relevant milestone is the agreement reached in 2010 between all political parties with parliamentary representation, which laid the foundations for the construction of a state policy in the sector. As a result of the implementation of this policy, Uruguay has practically decarbonized its electricity matrix, complementing the traditional

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participation of hydroelectric energy with the incorporation of wind, solar and biomass energy.

The high penetration of renewables in the electricity matrix has allowed Uruguay to position itself as a world-class player in the energy transition. The country ranks 13th in the Energy Transition Index ranking and is a leader in the region (World Economic Forum, 2021). In line with its sustainable policy, Uruguay has proposed a Long-Term Climate Strategy until 2050 (Uruguay Ministry of Environment, 2021), in which green hydrogen and its derivatives are used for long-distance heavy cargo and passenger transport, as well as for some industrial uses. Consequently, for both domestic consumption and export, green hydrogen will play an important role for the country in the short and long term.

SUSTAINABILITY POLICIES

Uruguay has a broad and robust package of public policies for sustainable development, which includes actions for climate, energy, agricultural production and waste. Historically, and independently of the different governments, the work has been promoted in a transversal way, articulating between the ministries of production and the environment, understanding that sustainability can only be developed in an integrated and coherent way with the other dimensions of development, including social. Examples of this are energy policies, climate change and forestry, among others.

Continuing the relevance of environmental issues of State policy, in 2020 the Ministry of the Environment was created, to add to the actions that prioritize sustainability issues on the agenda and give them greater institutional strength. Uruguay has been working transversally at the level of all ministries, autonomous entities and decentralized services, assuming the responsibility of orienting its public policies around the fulfillment of the Sustainable Development Goals (SDGs), in order to advance in each of them by the year 2030.

Since 2017, Uruguay has submitted voluntary reports and completed monitoring of the country's situation in each of the 17 SDGs (Presidency of the Republic, 2021). The promotion of green hydrogen will accelerate progress on SDGs 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities) and 13 (Climate Action), and will indirectly contribute to other goals.

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COMPETITIVE ADVANTAGES TO DEVELOP GREEN AND DERIVED HYDROGEN

The main competitive advantages that Uruguay has to be a relevant producer of green hydrogen and derivatives are described below, both for the local market and for exports.

Potential and complementarity of renewable energies.

Uruguay has great potential to install new electricity generation capacities from renewable sources, mainly wind and solar photovoltaics. The country has a very good combined wind and solar resource, both for its daily and seasonal complementarity; This allows for high capacity factors in the electrolyser and low hydrogen production costs.

According to the studies carried out, the characteristics of solar and wind renewable energy in Uruguay would make it possible to reach, in 2030, levelized energy costs (LCOE), with values that would be in the range between 16 and 19 USD/MWh. On the other hand, offshore wind would present costs in the range between 26 and 28 USD/MWh. Driven by CAPEX reductions and technological improvements, the trend of decreasing costs would continue over time (although moderating its fall), and would allow to reach costs of 11 USD/MWh by 2040 for the use of solar resources through photovoltaic technology, USD 15/MWh for wind energy and USD 21/MWh for offshore wind energy.

In the studies carried out, regions of the national territory with different renewable energy generation potentials are identified. (Uruguay Green Hydrogen Roadmap, 2021)

Electricity matrix with 97% renewable participation

For industrial processes that need to operate continuously (e.g. the production of e-Jet Fuel), the connection to the national electricity grid, with 97% renewable, as mentioned above, positively impacts the profitability of the investments required for the production of green hydrogen and derivatives (wind and solar photovoltaic plants complemented with hydrogen accumulation). For these cases, the advantage of a grid connection could translate into a decrease in the cost of hydrogen by between 5 and 10% compared to an investment exclusively in wind and solar photovoltaic installations disconnected from the grid and with hydrogen accumulation. (Uruguay Green Hydrogen Roadmap, 2021)

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High Water Availability

Uruguay has access to the Atlantic Ocean and many rivers, some of them with basins that cover important areas of countries in the region. Among the rivers with basins in other countries, the following stand out:

a) The Rio Negro, with a basin of approximately 40% of the area of Uruguay (70,714 km2; the basin covers areas of Brazil and Uruguay). The Rio Negro flows into the Uruguay River.

b) The Uruguay River, with a basin twice the size of Uruguay (339,000 km2; covers areas of Argentina, Brazil and Uruguay). It flows into the Río de la Plata.

c) The Río de la Plata, with a basin 17 times larger than the area of Uruguay (3,100,000 km2; covers areas of Argentina, Bolivia, Brazil, Paraguay and Uruguay). (Uruguay Green Hydrogen Roadmap, 2021)

National Analysis

In turn, the country has a very important rainfall and water availability regime, with an average annual rainfall of 1320 millimeters. All this makes the existence of fresh water very abundant and suitable for the production of green hydrogen.

But this year we had a significant water deficit that had a negative impact, especially in the South Zone of the country, declaring a Water Emergency in the country.

The estimated production of hydrogen for 2040, in this roadmap, is one million tons for various uses and derivatives. This would imply a consumption of 10 million m3 of water per year, taking into account that to produce one kg of hydrogen between 9 and 10 liters of water are needed. Therefore, hydrogen production by 2040 would require a very low volume of water, compared to current water uses in the country's agricultural and industrial sectors.

Biogenic CO2 Availability

For the production of synthetic fuels, such as e-methanol or e-Jet Fuel obtained from H2 and CO2, the country has biogenic CO2, associated with industrial facilities that exploit biomass from sustainable production, in the vicinity of areas with good availability of renewable resources. Uruguay is very well positioned in terms of sustainable development certifications in its forestry production: it reaches 80% in forest plantations and 100% in the level of products that have industrial processing in this sector (Society of Forest Producers

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of Uruguay, 2022). Based, among other aspects, on the development achieved by the forestry sector, and in particular by the industry associated with this production chain, bioenergy has become the main source of energy at national level since 2016. In this way, it displaced oil and its derivatives, the source that traditionally occupied this place, to a second position (Ministry of Industry, Energy and Mining Uruguay, 2021).

Logistics

Uruguay has access to the Atlantic Ocean, which allows the export of hydrogen and derivatives to Europe and the United States with shorter maritime distances than other countries with export potential. In this way, reduced transport costs are achieved. The port of Montevideo presents a development opportunity for the export of hydrogen derivatives.

The country does not have major geographical accidents and has access roads to the entire territory and infrastructures for the local transport of hydrogen and its derivatives. It is important to note that the Central Railway will make it possible to connect the area with the greatest renewable energy potential with the Port of Montevideo, providing great opportunities for the transport of hydrogen derivatives and facilitating their export possibilities. Similarly, the country has river and road transport that can help improve competitiveness in the transfer of export products. As a backdrop, in the energy sector, it can be mentioned that in the last decade Uruguay has faced and overcome multiple logistical challenges associated with the construction of generation infrastructure, large-scale industrial plants and transmission works, among others. As an indicator, it is indicated that in 2014, 60% of the special cargo (whether by size or weight) transported in the country corresponded to renewable energy projects. (Uruguay Green Hydrogen Roadmap, 2021)

WHY GREEN HYDROGEN?

Hydrogen is one of the most abundant resources on the planet and is regularly used in different industrial processes. It is a vector capable of storing and transporting energy, and can be used directly or for the production of energy inputs.

So what was the news? In a scenario of global decarbonization by 2050 and in the sectors with the greatest difficulty in reducing emissions, renewable energies (Solar and Wind, which are in the process of reducing costs, and water allow us to produce green energy inputs with minimal environmental impact). That is why the European Union, the

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United States, the United Kingdom, Japan (among others) have chosen hydrogen as one of the main vectors that will allow the decarbonization of the sectors of the economy that have the greatest difficulty in reducing their climate footprint.

Hydrogen allows the electrification of long-distance land cargo transport, but also its application through known chemical processes allows the production of green fuels such as methanol from renewable sources, ammonia, green kerosene, synthetic diesel. It is these green fuels and chemicals that make it possible to decarbonise maritime and air transport, fertilisers and the production of steel and cement, among others.

The process to achieve the energy transition is gaining momentum in the world, through strategies such as electromobility (a path that Uruguay has already started) and green hydrogen. Significant funds have been committed to the development of a hydrogen economy and it is a strategic item on the agenda of major global countries and companies. Energy geopolitics is starting a transition process towards greater diversification in which countries that historically have not had relevant energy resources are positioning themselves as new players with diverse roles and possibilities.

Uruguay faces a unique opportunity to expand the country's energy production and export frontier. The first energy transition showed us the production of renewable potential and strengthened our credibility as a country that receives large investments. Seeking to move from sun and wind to hydrogen, which will allow the production of exportable synthetic fuels.

IMPACT ON LOGISTICS

Green hydrogen is emerging as one of the most promising energies in the fight against climate change and its impact on logistics could be significant. Here are some aspects that may be affected:

Freight transport

As we already know that land transport is one of the main emitters of greenhouse gases in the world, generating approximately 830 million tons of CO2 per year in the atmosphere (according to the International Energy Agency) for this reason we seek to mitigate this contamination and this contaminating impact, with Green Hydrogen being one of the main options according to our work in this article, since its use as a fuel in the transport of goods would emit only water vapour and leave no polluting residue in the air,

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contributing to more sustainable logistics, which would significantly reduce the carbon emissions associated with the transport of goods.

In addition to the advantages for cargo transport and care for the environment, we must indicate that there are some difficulties since the production of Green Hydrogen fuel has a cost that will impact the final price of the product and the other disadvantage is that the development and technology studies for such production are slow and lack investments.

Energy Storage and Distribution

Green hydrogen can also serve as a way to store renewable energy. Given that electricity production from renewable sources can be intermittent, excess energy can be used to produce green hydrogen through water electrolysis. This hydrogen can be stored and used at times when energy demand exceeds supply. This would provide a solution to address the challenges of variability in renewable energy production and ensure a constant supply of energy.

Power generation on board ships and aircraft

The use of green hydrogen could also have an impact on maritime and air transport. At the moment, ships and planes use highly polluting fossil fuels. The use of green hydrogen as an alternative fuel in these sectors would significantly reduce carbon emissions and contribute to more sustainable logistics.

Fuel Supply Infrastructure

To make the most of green hydrogen in logistics, it would be necessary to build an adequate supply infrastructure. This entails the creation of hydrogen charging stations, as well as the integration of hydrogen storage and distribution systems. It will involve a joint effort by industry, governments and regulators to create this infrastructure and ensure its availability worldwide, which will favor both the increase of labor in the industrial sector and social and economic development in the generation of direct jobs.

OPINION OF THOSE INVOLVED IN THE PROJECT

For this article, the author interviewed Engineer Fernando Schaich- founder of SEG Ingenieria-Vice-President of the Uruguayan Chamber of Commerce and Industry- CEO of

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SEG Greenpower, a company of the SEG INGENIERIA group dedicated to the development of large-scale renewable energy and green hydrogen projects.

Being chosen because he was a direct member of one of the most important projects in Uruguay, the interview had two topics to address:

Topic 1: What is the current situation of Green Hydrogen in Uruguay?" It points out the following." Today two major projects are underway, the Paysandu "Department" located in the northwest of Uruguay bordering to the north with Salto and to the east with Tacuarembo and to the west with the Uruguay River that separates it from the Argentine Republic has an area of 13,922 square kilometers," where the Chilean company HIF GLOBAL will allocate US$ 4 billion for the production of Green Hydrogen and electronic fuels and the Green Hydrogen Hub Drum in Tacuarembo" Department located in the north center of Uruguay, bordering to the north with Rivera, to the south with the Río Negro and to the west with Salto and Paysandu, it has an area of 15,438 square kilometers, where the German company Enertrag with the local technical support of Greenpower (part of the SEG Ingenieria group) will have its first Green Hydrogen plant with the capacity to produce 15,000 tons of green hydrogen per year... they are also working on a smaller project such as the H24U that was awarded to the company Saceem - CIR with the participation of the company Air Liquid, technical support of the SEG Ingenieria group, with an initial investment of US$ 43 million, being the first pilot of green hydrogen production in the country, to be launched in trucks for forest transport..."

Topic 2 : What is the impact on Logistics in Uruguay? Next, I emphasize that I see this as very favorable for Uruguay, this being a new development opportunity for the country, since new factories are planned that will require labor will also have an impact on socioeconomic development and, most importantly, on its impact on the environment, I see the port infrastructure (Port of Montevideo) as a challenge, especially with regard to the storage of Green Hydrogen derivatives, considering whether it complies with the Green Hydrogen Roadmap in Uruguay where the necessary improvements are projected... "It concludes that" the production of Green Hydrogen does not have a high consumption of water as the figures mentioned in public opinion "contextualize that..." for the production of Green Hydrogen, water consumption is infinitely lower than agricultural and livestock

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farming..." also clarifies that the Green Hydrogen Hub Drum project will consume seven times less water than the 5"Termas do Arapey."

RESULTS

In this article, it has been proven that green hydrogen has significant potential to impact logistics in a positive way. From reducing carbon emissions in freight transport to providing a viable solution for storing renewable energy, its adoption can transform logistics into a more sustainable sector in line with global goals to combat climate change. However, the large-scale deployment of green hydrogen in logistics requires a coordinated effort between industry and governments to ensure that the transition results in a product that is true and environmentally friendly.

A strategic element that strengthens this initiative is Law No. 16,246, known as the "Ports Law". This legislation establishes a Free Port regime in Uruguay, creating a highly competitive environment for the transit of goods. As described in article 2 of the law, "the circulation of goods in the Port of Montevideo will be free of charge, without the need for authorizations or formal procedures." This allows for a series of logistical activities, such as depositing, repacking, and moving goods, with no restrictions on their destination. This flexibility makes the Port of Montevideo a crucial logistical attraction for international trade and for the insertion of green hydrogen in global supply chains.

Currently, Uruguay has three major green hydrogen production projects underway. The first is the H24U project, which, through a pilot plan, was developed with the support of the Green Hydrogen Sector Fund of the National Agency for Innovation and Research, with an investment of US$ 43 million. The project includes 17 heavy-duty trucks adapted to operate with green hydrogen, transporting forest cargo to UPM, one of the largest pulp mills in the country, located in the center of the national territory (Pueblo Centenario, Durazno).

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[5]Termas do Arapey: Tourist site of hot springs with an average temperature of 39ºC of the Guarani Aquifer, located in Salto since the early 40s, which annually receives about 150 thousand tourists

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warehouse, repackaging, and movement of goods, without restrictions on their destination. This flexibility makes the Port of Montevideo a crucial logistical attraction for international trade and for the insertion of green hydrogen in global supply chains.

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The second project under development is the Tambor Green Hydrogen Hub, with an investment of US$ 628 million by the German company Enertrag, in partnership with the Uruguayan company SEG-Ingeniería. This project, located in Tambores, Tacuarembó, is the first major green hydrogen exploration project in the country, with the production of methanol from green hydrogen generated in wind and photovoltaic plants. The goal is to produce up to 15 thousand tons of methanol per year.

The third and most recent project is led by Chilean company HIF Global, which will build a green hydrogen and e-fuels plant in Paysandu. With an investment of US$ 4 billion, the largest foreign investment in Uruguay, this plant will allow the decarbonization of up to 150 thousand vehicles per year, becoming a milestone in the country's energy transformation.

CONCLUSION AND FUTURE WORK

FINAL CONSIDERATIONS MAKE A STRUCTURE THAT PRESENTS THE GENERAL OBJECTIVE, A PARAGRAPH OF EACH SPECIFIC OBJECTIVE PROPOSED, LIMITATIONS AND SUGGESTIONS FOR FUTURE STUDIES

This article aimed to evaluate the impacts of the Uruguayan green hydrogen project on National Logistics, focusing on the socioeconomic and infrastructure challenges related to the production, storage, distribution and export of this fuel.

It has been found that green hydrogen can replace fossil fuels in various logistics sectors, such as road, sea, and air transport, resulting in a significant reduction in carbon emissions and contributing to the decarbonization goals set globally. It was noted that the project will require the development and adoption of new technologies such as fuel cells

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and hydrogen storage systems that can drive technological innovation in the sector, creating employment opportunities and economic development.

The socioeconomic challenges were observed, including the high initial costs of the transition to green hydrogen, as they require significant investments in infrastructure and technology. The adoption of new technologies will require the qualification and training of workers. This can be a challenge, especially in areas where skilled labor is in short supply. Training and education programs will be essential to ensure a smooth transition. All these expenses can pose a challenge for small and medium-sized companies, which may not have the necessary financial resources. It was also observed that social acceptance of the new technology can be a challenge due to concerns about the safety of using green hydrogen. Therefore, awareness campaigns and community engagement will be necessary to ensure public support. More sustainable logistics can improve the corporate image of companies and meet consumer demands for greener practices.

By analyzing the internal challenges both in relation to the business sector, infrastructure and in relation to society,

With regard to the specific objective of determining with those involved in the projects the advantages and disadvantages of the development of green hydrogen projects in Uruguay, it was observed that

I. Uruguay has great potential to install new electricity generation capacities from renewable sources, mainly wind and solar photovoltaics. The country has a very good combined wind and solar resource, both for its daily and seasonal complementarity; This allows for high capacity factors in the electrolyzer and low hydrogen production costs
II. For industrial processes that need to operate continuously (e.g. the production of e-Jet Fuel), the connection to the national electricity grid, with 97% renewable, as mentioned earlier, positively impacts the profitability of the investments required for the production of green hydrogen.
III. With high availability of water, Uruguay has access to the Atlantic Ocean and many rivers, some of them with basins that cover important areas of countries in the region.
IV. Uruguay has access to the Atlantic Ocean, which allows the export of hydrogen and derivatives to Europe and the United States with shorter maritime distances than other countries with export potential. In this way, reduced transport costs are

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achieved. The port of Montevideo presents a development opportunity for the export of hydrogen derivatives.

Regarding the importance of the Government with sustainable commitment policies set out in the Green Hydrogen Roadmap in Uruguay, it was seen that the sustainable commitment policies established in *the Green Hydrogen Roadmap* are essential to align government actions with climate, economic and social objectives. They provide the necessary support for Uruguay to not only adopt green hydrogen as a new energy source, but also to position the country as a global leader in energy sustainability.

In addition to the logistical and environmental benefits, this article also discussed the challenges for the development of sustainable logistics based on green hydrogen. Although Uruguay already has a highly sustainable energy matrix, with 97% of its energy coming from renewable sources, there is still a need to develop specialized labor and expand academic knowledge in this area. The development of the second energy transformation, driven by the adoption of green hydrogen, is viewed with optimism by both the business sector and the Uruguayan government.

As a recommendation for future work, it is suggested that this article be expanded into a master's thesis, delving into the energy and logistical issues related to green hydrogen, with an emphasis on sustainable development and Uruguay's logistics competitiveness.

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