H2U

Uruguay’s Roadmap for **Green Hydrogen and Derivatives**

Ministry
of Industry,
Energy and Mining

H2U

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Interinstitutional group:

Ministry **of Industry, Energy and Mining**
Ministry **of Environment**
Ministry **of Foreign Affairs**
Ministry **of Economy and Finance**

Office **of Planning and Budget**
Ministry **of Transport and Public Works**
Ministry **of Housing and Territorial Planning**
Ministry **of Defense**

Collaborating institutions:

ANCAP, UTE, ANII, ANP, AUCI, CONICYT, LATU, Uruguay XXI, URSEA, ANDE

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This document is the result of the work done by the interinstitutional group on green hydrogen and derivatives coordinated by the MIEM, the consultation process with the private sector, civil society and academia, and the support provided by the IADB in 2021 and early 2023.

This report has been prepared paying special attention to the use of expressions and concepts that do not exclude people by gender. In some cases, in order to avoid grammatical overload, the generic masculine has been used on the understanding that it indiscriminately designates men and women, without therefore being interpreted as a sexist use of language. This document is as follows: Uruguay's Roadmap for Green Hydrogen and Derivatives, MIEM 2023. www.miem.gub.uy | www.hidrogenoverde.uy

This document is a technical input developed by the above-mentioned interinstitutional group for the Uruguayan State to design the relevant public policies to develop the industry of green hydrogen and derivatives. In no case shall this document be legally binding.

Translation to English with the support of the International Power-to-X Hub implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Design: 3Vectors / Laura Scaron

Photos: MIEM's photobank, Uruguay XXI's photobank and unsplash.com

ACRONYMS

ANCAP	National Administration of Fuels, Alcohol and Portland (in Spanish, *Administración Nacional de Combustibles, Alcohol y Pórtland*)
ANII	National Agency for Research and Innovation (in Spanish, *Agencia Nacional de Investigación e Innovación*)
ANP	National Ports Administration (in Spanish, *Administración Nacional de Puertos*)
CONICYT	National Council for Innovation, Science and Technology (in Spanish, *Consejo Nacional de Innovación, Ciencia y Tecnología*)
DINACEA	National Directorate of Environmental Quality and Evaluation (in Spanish, *Dirección Nacional de Calidad y Evaluación Ambiental*)
DINAGUA	National Water Directorate (in Spanish, *Dirección Nacional de Agua*)
DRI	Direct Reduced Iron
e-Jet Fuel	Aviation fuel, in this case, made from green hydrogen
ESG Factors	Environmental, Social and Governance Factors
Gt	Gigatoneladas
GW	GigaWatt
IADB	Inter-American Development Bank
IMO	International Maritime Organization
LATU	Technological Laboratory of Uruguay (in Spanish, *Laboratorio Tecnológico del Uruguay*)
MA	Ministry of Environment (in Spanish, *Ministerio de Ambiente*)
MEF	Ministry of Economy and Finance (in Spanish, *Ministerio de Economía y Finanzas*)
MIEM	Ministry of Industry, Energy and Mining (in Spanish, *Ministerio de Industria, Energía y Minería*)
MDN	Ministry of National Defense (in Spanish, *Ministerio de Defensa Nacional*)
MVOT	Ministry of Housing and Territorial Planning (in Spanish, *Ministerio de Vivienda y Ordenamiento Territorial*)
MRREE	Ministry of Foreign Affairs (in Spanish, *Ministerio de Relaciones Exteriores*)
Mt	Megatons
MTOP	Ministry of Transportation and Public Works (in Spanish, *Ministerio de Transporte y Obras Públicas*)
Offshore wind energy	Energy generated by sea-based wind turbines
Onshore wind energy	Energy generated by land-based wind turbines

OPP	Office of Planning and Budget (in Spanish, *Oficina de Planeamiento y Presupuesto*)
SAF	Sustainable Aviation Fuel
SDGs	Sustainable Development Goals
TCO	Total Cost of Ownership
URSEA	Energy and Water Services Regulatory Unit (in Spanish, *Unidad Reguladora de Servicios de Energía y Agua*)
USD	United States Dollars
UTE	National Administration of Power Plants and Electric Transmissions (In Spanish, *Administración Nacional de Usinas y Trasmisiones Eléctricas*)

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FOREWORD

Green hydrogen and new energy carriers

A strategy towards prosperity based on our competitive advantages; promoting the new green economy as a source of development.

Uruguay has started its second energy transition, the next step towards reducing fossil fuel consumption. It contributes to the national goal of achieving carbon neutrality by 2050 under the country's 2021 Long-Term Climate Strategy. This second energy transition rests on three pillars: **energy efficiency, electromobility, and the electrification of demand.** Additionally, we are **committed to green hydrogen and derivatives** for hard-to-abate industries.

Green hydrogen is produced through water electrolysis using renewable electricity. This energy carrier does not come from fossil fuels and helps decarbonize industries such as long-distance road transport, energy-intensive industries, and maritime and air transport, among others.

Hydrogen has been widely used for many decades in various applications. Therefore, green alternatives not dependent on fossil fuels are possible when green hydrogen is used.

Thus, hydrogen can be used in a fuel cell to regenerate electricity, power a cellular radio base in a remote location, or move an electric vehicle ("hydrogen vehicles"), among other fuel cell applications. It can also replace natural gas in many heat-dependent applications. Also, vegetable oil can be hydrogenated, and HVO—a precursor of synthetic, green fuels—can be produced. Hydrogen can also be used to reduce iron oxide (iron ore extracted from mines) to produce iron (Direct Reduction Iron = DRI) and steel without fossil fuels. This is one of the hardest industrial processes to decarbonize.

Furthermore, Uruguay is uniquely positioned to combine hydrogen with carbon dioxide (CO_2) of biological origin (biogenic CO_2) and produce green methanol. This methanol can produce gasoline, gas, oil, or jet fuel identical to the fuels we know but synthetic, i.e., not derived from oil.

Uruguay produces large amounts of biogenic CO_2 in biomass plants, which burn forest or agricultural waste to produce electricity, and from biofuel production processes that emit CO_2 from fermentation or other agro-industrial processes. We can then produce these new energy sources that entirely replace conventional fuels from our renewable resources (transformed into green hydrogen) and agro-industrial waste.

Can we produce the renewable electricity we need? Uruguay has more renewable resources than it would need to meet its current and future needs. The wind and sun in Uruguay make our land ideal for renewable electricity generation. Additionally, several studies show that our potential is much greater than the future needs of our electricity system. Wind and sun are complementary resources in Uruguay because their intensity changes at different times of the day, the year, and the seasons. In other words, combining both sources results in more stable electricity generation. In addition, the best locations for solar and wind sources are in approximately the same areas, which are also close to land with abundant biogenic CO_2.

Water is abundant in Uruguay, and its use under our green hydrogen strategy will be much lower than the current agricultural, industrial and residential uses. Professional water management can ensure that this industry will have no adverse effects on water resources in Uruguay, as explained below.

Finally, Uruguay is well known for its stability, transparent legal framework, attractive business environment, and reputation for honoring contracts and its commitments. This makes Uruguay an attractive country for these large projects.

Uruguay has abundant resources to generate renewable electricity, water, and biogenic CO_2 in volumes far above the demands of our economy.

Therefore, it is the right place to develop a new green energy export industry that can attract large-scale project investment and provide the world with the necessary inputs for the energy transition we need.

Uruguay will develop a new green energy export industry based on native resources that will add value, create jobs, and attract investment and technology. Our energy transition strategy will become a new source of added value for the national economy and have potential similar to our traditional export industries. Most importantly, this industry will contribute to our people's well-being by creating quality jobs, conducting works, promoting investment, and a decentralized industry. This will create a new link in our agro-industrial chains. This is a great opportunity that we must harness as it will position us as leaders worldwide. It is a step on the road to development. We must make the most of this opportunity.

Omar Paganini,
Minister of Industry, Energy and Mining

1. EXECUTIVE SUMMARY

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The ambitious global decarbonization targets for 2050 require accelerated and significant changes regarding the energy sources and raw materials used in industrial processes.

Uruguay has almost fully decarbonized its electricity matrix and holds a prominent position worldwide, with a > 90% use of renewable energies (94% in 2016–2022). This achievement is followed by the local challenge of decarbonizing the rest of the energy matrix (currently approximately 40% fossil fuels), mainly in the transport and industrial sectors.

To this end, the low-emission energy transition requires new sources of energy locally and globally. This is because emissions are challenging to reduce in some industries because they cannot use renewable electricity directly (e.g., maritime, aviation, or some industrial sectors). This means that more extraordinary efforts should be made to diversify renewable energy sources that are more resilient over time and help decrease future risks.

In this context, producing new, more renewable energy sources—in particular, green hydrogen, made from water and renewable energies and with the capacity to decarbonize different uses (transport, industry, power generation and raw materials)—has become a hugely relevant carrier on the global agenda. In a scenario of projected high demand in Europe and East Asia, some countries will import, and others will export low-emission hydrogen. Uruguay meets the conditions to be an export country.

This document presents the potential key areas of development for the economy of green hydrogen and its derivatives in Uruguay, the goals that could be achieved, and the main challenges to address. This analysis is based on national resources, the progress of technological development, research on market conditions, analysis of competitors and the potential social and environmental benefits for Uruguay.

The quality, abundance and complementarity of the country's wind and solar resources ensure the continuity of the energy transition process, and Uruguay would have competitive costs in hydrogen production at scale. By 2030, green hydrogen production costs could reach 1.2–1.4 USD/kg, with a renewable energy installation potential of over 90 GW at sites with the best wind and solar resources.

Additionally, Uruguay has the unique potential to produce new green hydrogen-based products like green fuels, raw materials, and fertilizers. This requires carbon dioxide (CO_2) from plants, which can be obtained from domestic industries using sustainable biomass in their production processes. H_2 derivatives could use the logistical infrastructure and ports available in the country for commercialization and export purposes.

Uruguay has decades of experience in renewable energy projects, solid regulatory frameworks, political, institutional and legal stability and macroeconomic soundness. This makes the country attractive for sustainable investment, particularly for projects including hydrogen and its derivatives for the local and export markets.

Given this framework, and based on rational and balanced management of its natural resources, Uruguay could first aim for the **domestic market for the use of hydrogen and derivatives for heavy and long-distance transport and green fertilizer production.** An export market for hydrogen derivatives, such as green fuels and raw materials, could drive this market. In the last stage, hydrogen and green ammonia could be exported directly, and offshore green hydrogen production could be promoted.

By 2040, hydrogen production could amount **to one million tons per year**. This will require the installation of approximately **18 GW of renewables and 9 GW of electrolyzers.**

One of the main challenges is planning the strategy in a coordinated and organized fashion and creating regulations that reassure the population and project developers. This must be done jointly with several national institutions.

Uruguay must promote a communication and citizen participation plan, build domestic capacities, promote research and innovation, and analyze the need for common infrastructures from the initial development stages.

Green hydrogen and its derivatives amount to a potential USD 1.9 billion revenue/year opportunity for Uruguay by 2040.

Developing the green hydrogen industry could create over 30,000 direct skilled jobs in plant construction, operation and maintenance, logistics and technical education. It could lead to a new socio-economic growth sector and contribute to decarbonizing other national productive activities.

A national green hydrogen economy will help diversify Uruguay's production matrix by increasing the added value through a new industrial link and developing the export potential to new markets worldwide, significantly contributing to economic growth.

The Government of Uruguay considers green hydrogen a priority in its sustainability program.

2.
COLABORATION AND METHODOLOGY

2. COLLABORATION AND METHODOLOGY

Uruguay began working on developing green hydrogen production in 2018 by creating a group that included the Ministry of Industry, Energy and Mining (MIEM) and state-owned energy companies ANCAP and UTE. In this first stage, developing green hydrogen after decarbonizing the electricity matrix was considered a natural step for Uruguay. The medium and long-term opportunities of decarbonizing the energy sector (heavy road, maritime and air transport, industry, etc.) and raw materials were already envisaged. Additionally, green hydrogen is a carrier that allows renewable energy to be distributed among sectors and regions. At the time, we focused on analyzing green hydrogen production from renewable energies and its use in heavy and long-distance transport in the Verne Project.

In 2020, the MIEM becomes the green hydrogen leader and starts working with an interinstitutional hydrogen group that includes ministries and State institutions. That same year, Uruguay worked with the Port of Rotterdam (PoR), the Netherlands, on preliminary studies to identify Uruguay's potential as a producer and exporter of green hydrogen and derivatives to Europe. The Inter-American Development Bank (IADB) provided its ongoing support and close collaboration until the first conclusions of the work were published (Inter-American Development Bank, 2021).

During 2021, progress was made in developing this roadmap. First, Mc-Kinsey & Company was hired (as per contract C-RG-T3777-P001 entered into with the IADB) to conduct technical studies to support this document.1

1 Further information about these inputs can be found at https://publications.iadb.org/es/ hidrogeno-verde-y-el-potencial-para-uruguay-insumos-para-la-elaboracion-de-la-ho-ja-de-ruta-de

As part of this process, three meetings were held with relevant stakeholders (discussion roundtables), which included over 70 national and international representatives at each meeting. The scope of each roundtable is detailed below.

Roundtable 1: ***Supply and demand of green hydrogen and derivatives.*** Production costs in Uruguay: levelized cost of electric energy (LCOE), levelized cost of hydrogen (LCOH), and cost of hydrogen derivatives. Potential domestic and export market.

Roundtable 2: ***Enablers and barriers.*** Regulatory aspects include permits, financing, bilateral agreements, infrastructure, training needs, and social licenses.

Roundtable 3: ***Initial green hydrogen roadmap proposal.*** Key milestones, socioeconomic benefits, risk analysis.

The draft Roadmap was launched publicly on 14 June 2022 and submitted to public consultation through different mechanisms:

1. It was published on the MIEM's website and remained open to comments from the public for a year.
2. Workshops were held with civil society, academia, and the private sector from August to November 2022.
3. The MIEM presented the document to the main political parties, the Congress of Mayors and Senators, and Deputies within the Science, Innovation and Technology Commission of the National Congress.

The interinstitutional group that worked during the Roadmap preparation period included the Ministry of Industry, Energy and Mining (MIEM), the Ministry of Environment (MA), the Ministry of Economy and Finance (MEF), the Ministry of Transportation and Public Works (MTOP), the Ministry of National Defense (MDN), the National Ports Administration (ANP), the National Agency for Research and Innovation (ANII), Uruguay XXI, ANCAP, UTE and the Technological Laboratory of Uruguay (LATU).

After this process of analysis and exchange with relevant national and international stakeholders, it is concluded that Uruguay has excellent conditions for developing green hydrogen and derivatives, both for local use and export. This conclusion is the basis for this roadmap to 2040. Presidential Resolution 294/2022[2] promotes the H_2U program and institutionalizes a broader interinstitutional working group.

2 https://www.gub.uy/presidencia/institucional/normativa/resolucion-n-294022-se-en-comienda-ministerio-industria-energia-mineria

3.
WHY **GREEN HYDROGEN?**

3. **WHY GREEN HYDROGEN?**

Green hydrogen is critical to achieving ambitious global decarbonization goals, particularly in the sectors where it is most difficult to reduce greenhouse gas emissions. Hydrogen is highly versatile as it can be used directly or combined with other elements to produce new products. It can be used in land, sea and air transportation, industrial use, power generation, and raw material production.

3.1. **Global situation**

According to studies by the Intergovernmental Panel on Climate Change (IPCC), the world must achieve carbon neutrality by 2050 to limit global warming to 1.5°C (IPCC, 2018).

Fossil fuels account for 80.2% of global energy consumption (Renewables–REN 21, 2021). Demand will continue to increase as the world's population grows and further economic development is projected. Therefore, accelerating a low-carbon energy transition is urgent and a priority.

Globally, each country takes actions to reduce greenhouse gas emissions under the Paris Agreement (2016) and in the context of the United Nations Framework Convention on Climate Change. Many have already set the goal of being carbon neutral by 2050 (United Nations, Climate Change, 2022), and regulations are being developed (European Commission–Climate Action, 2022).

As a result, industries are making announcements along these lines. Major automotive brands have announced that their vehicles will be zero-emission by 2050, some even earlier (General Motors, 2022). Shipping and aviation companies have begun to develop their decarbonization plans to gradually include hydrogen and green fuels in their fleets (Maersk, 2022; Airbus, 2022; Boeing, 2022).

Other energy industries have also announced that they will be zero-emission by 2050, including companies whose core business is selling hydrocarbons (Shell, 2022; British Petroleum, 2022).

Hydrogen, generated from low-emission energy sources, is essential to achieve net-zero emissions by 2050. It can avoid 80 Gigatons (Gt) of cumulative CO_2 emissions and help achieve 20% of the reduction needed by 2050. This requires 660 million tons of renewable, low-carbon hydrogen, equivalent to 22% of the global final energy demand in 2050 (McKinsey & Company, 2022).

The estimated demand for hydrogen and its derivatives in Europe and some Asian countries is so high that it will have to be imported from further afield to meet the established targets (World Energy Council, 2021).

3.2. **The role of green hydrogen in the energy transition**

Green hydrogen contributes in various aspects to the energy transition underway to ensure compliance with the environmental goals set for 2050. The main contribution identified is that green hydrogen production and use would help decarbonize energy and raw material end uses, which is difficult to achieve in other ways or that cannot be achieved directly with renewable energies or direct electrification.

First, this energy carrier allows the system to distribute energy to other sectors. Thus, electricity from renewable sources can be used to produce hydrogen for a wide variety of uses, such as producing fuel for mobility in heavy vehicles and hydrogen derivatives for maritime and aviation use, synthesizing ammonia for fertilizers, industrial heat, in some climatic conditions, the thermal conditioning of buildings, and the direct reduction of iron for steel production, etc. (see Figure 1).

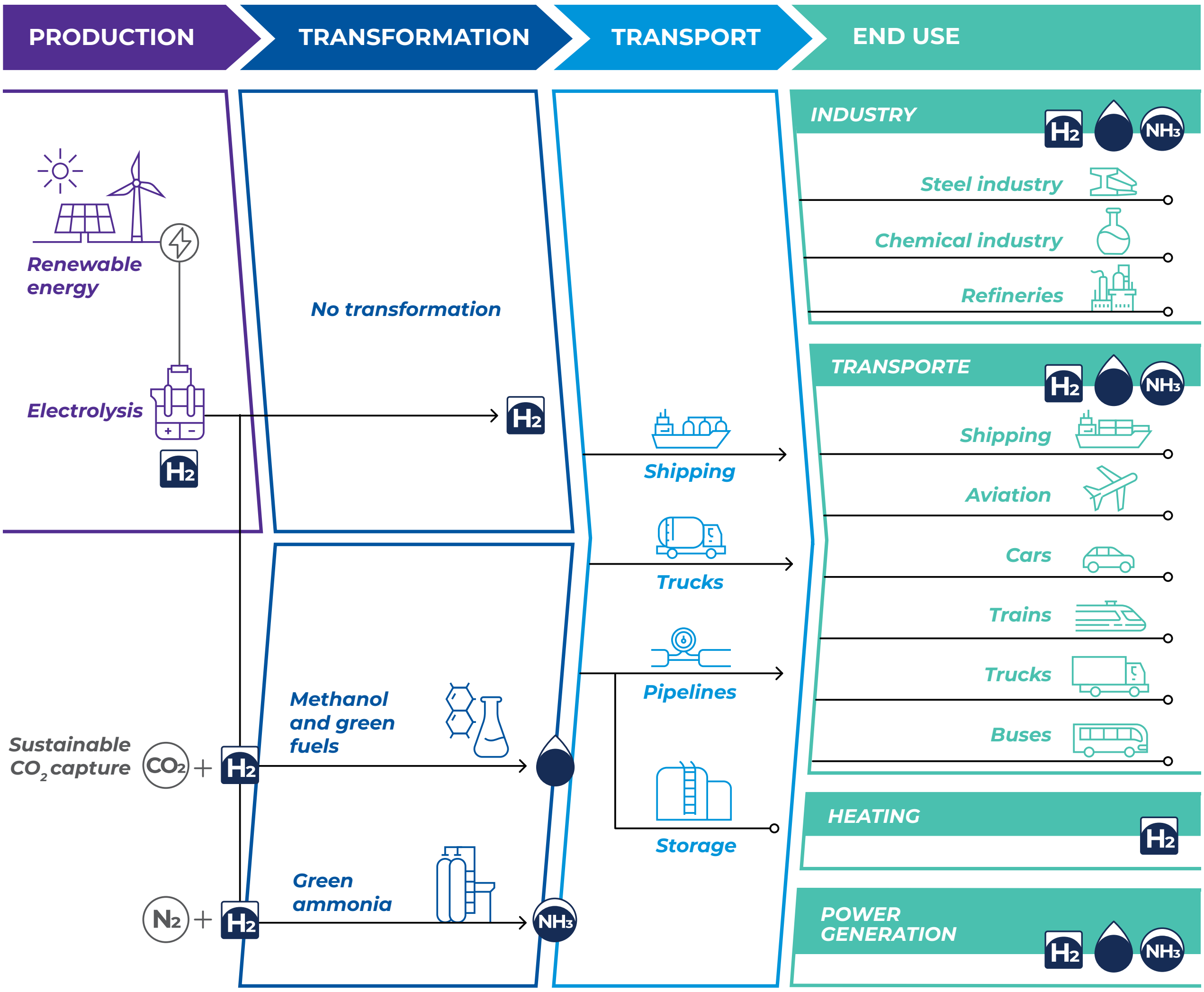


Figure 1: Uses of hydrogen in different sectors as an energy source or raw material.

Source: Based on the International Renewable Energy Agency document entitled "Green Hydrogen: A guide to policy making" (International Renewable Energy Agency, 2020).

Green hydrogen also contributes to the energy transition by increasing the energy system's resilience as it integrates renewable energies on a large scale.

Using green hydrogen and its derivatives as a carrier allows us to transport green energy across regions, as it can be transported over long distances, similar to other energy sources (e.g., oil or liquefied natural gas). In this way, it would be possible to transport renewable energies in the form of green hydrogen, derivatives, or green products from world regions that can produce renewable energies in abundance and inexpensively to areas with insufficient resources (or surface area for energy transformation) or where production would be too costly. The storage of hydrogen and hydrogen derivatives in large quantities and for long periods of time allows the country to increase the share of renewable energies in the energy system and contribute to the continuous operation of the grid, balancing the peaks and valleys of electricity demand and storing energy at times of high availability and low cost to be delivered when demand requires it. It would also contribute to diversify energy resources in different regions by facilitating the use of the most attractive and profitable resources. It can also provide greater security to distributors, ensuring a continuous supply to essential facilities (e.g., health services and data centers (Hydrogen Council, 2021).

In the electricity sector, it would also enable the generation of electricity from hydrogen or derivatives in a complementary way, thus helping achieve seasonal balance, backup for variable renewable sources, and continuous operation at the base.

Additionally, it would help countries that cannot generate electricity from renewable

sources to import hydrogen and derivatives and use them as an input in renewable electricity generation (Hydrogen Council, 2021).

Finally, green hydrogen would contribute to the ongoing transition by providing countries with greater energy security in the medium term since it can be produced locally or, potentially, imported from many producing countries spread across multiple regions. This contrasts with the current energy system, in which fossil fuels (80% of the world's energy matrix) (Renewables – REN 21, 2021) are produced by few countries at prices subject to variations due to causes beyond the control of importers.

These possibilities will develop over time: some with a greater degree of consolidation than others, based on the technological investments currently made globally, the production costs obtained on a commercial scale, and the development of international markets.

3.3. **Water and green hydrogen**

The water needed for green hydrogen production is used in the electrolyzers and as an input in the industrial process.

Any water can be used for hydrogen production. Water sources include surface or groundwater, fresh water, salt water, and even wastewater. Regardless of the source, a water purification plant is needed to remove impurities that may interfere with electrolysis. The volume of water used in electrolysis will depend on the water source and the conditioning required for the process.

Furthermore, heat is generated during electrolysis, and a cooling process is necessary. Several technologies can be used for this purpose. The most widely used technology recirculates water with a small amount of fresh water replenishment.

Thus, water use is different, and a combination of sources may be used based on the production scale and water availability at the project location.

The water requirements for green hydrogen are stoichiometrically calculated at 9 liters of water per kg of hydrogen. However, a more conservative consideration states that water use can range between 18 and 30 liters, depending on the source and technology used (Irena, 2023).

These values represent a water use similar to other industrial projects and significantly lower than the amount of water used for irrigation and other productive activities.

4.

¿WHY **GREEN HYDROGEN** IN URUGUAY?

4. ¿WHY GREEN HYDROGEN IN URUGUAY?

Developing green hydrogen is a natural step in Uruguay's decarbonization process, after significantly decreasing the use of fossil fuels in the electricity matrix. In addition, Uruguay has significant competitive advantages to become a relevant producer of green hydrogen and derivatives for the domestic and export markets.

4.1. **A country that promotes sustainable strategies**

In the first stage of this energy transition, Uruguay has almost completed the decarbonization of electricity generation. This is equivalent to a share of renewables in the electricity matrix of more than 90% (94% between 2016 and 2022), although the figure varies depending on the climatic characteristics of each year (see Figure 2). 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 several challenges, among them decarbonizing the rest of the energy sector (transport and industry) and the raw materials for industrial use, developing new energy sources such as green hydrogen and its derivatives, maintaining the high share of renewable energies in the electricity matrix, and promoting more efficient use of the electricity system.

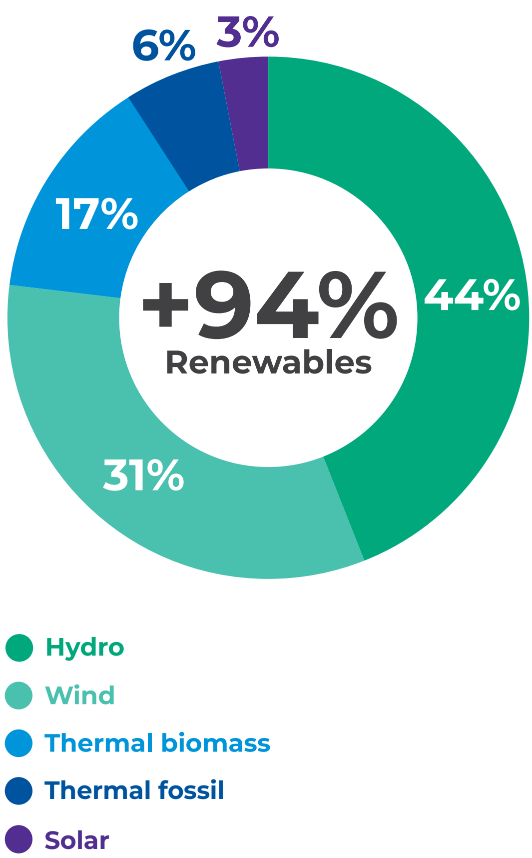


Figure 2: Electricity generation in Uruguay – Average for 2016 to 2022.

Source: MIEM (ben.miem.gub.uy).

4.1.1. Energy policy and first stage of the transition

In 2008, Uruguay presented its energy strategy, explicitly stating its commitment to renewable energies and energy efficiency. First, the policy seeks to go beyond the traditional reductionist vision based on a technical-economic analysis by including geopolitical, environmental, social, ethical, and cultural considerations. Moreover, this public policy promotes long-term vision and planning. Its most relevant milestone is perhaps the agreement reached in 2010 between all the political parties represented in parliament, which laid the foundations for developing a State policy in the sector.

Implementing this policy has allowed Uruguay to practically decarbonize its electricity matrix, complementing the traditional participation of hydroelectric energy by adding wind, solar, and biomass energy.

The high penetration of renewable energies in the electricity matrix has positioned Uruguay as a world-class stakeholder in the energy transition. The country ranks 13th in the Energy Transition Index and is the leader in the region (World Economic Forum, 2021).

In line with its sustainable policy, Uruguay has proposed a Long-Term Climate Strategy towards 2050 (Ministry of Environment Uruguay, 2021), in which green hydrogen and its derivatives are used for heavy-duty and long-distance passenger transport and some industrial purposes. Consequently, green hydrogen will be relevant for Uruguay for domestic consumption and export in the short and long term.

4.1.2. Sustainability policies

Uruguay has broad and robust public policies for sustainable development that cover climate action, energy, agricultural production, and waste.

Historically, and regardless of the administration in office, the work has been done cross-cuttingly by coordinating the interaction between the ministries of production and the ministry of environment. It is understood that sustainability can only be achieved in an integrated and coherent manner with the other development dimensions, including the social dimension. Some examples are climate change, forestry policies, and the law on land use.

Environmental issues are very relevant to Uruguay's national policy. Consequently, the Ministry of Environment was created in 2020 to contribute to the actions that prioritize current sustainability issues and consolidate their institutional strength.

Uruguay is working in a cross-cutting manner with all the ministries, autonomous bodies, and decentralized services. It has now assumed the responsibility of guiding its public policies regarding attaining the Sustainable Development Goals (SDGs) to advance them towards 2030. Since 2017, Uruguay has been submitting voluntary reports and has fully monitored the country's situation in each of the 17 SDGs (President of the Republic, 2021).

Boosting green H_2 will accelerate progress on SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) and indirectly contribute to attaining the other goals.

4.2. **Competitive advantages for developing green hydrogen and derivatives**

Uruguay's main competitive advantages to become a relevant producer of green hydrogen and derivatives for the domestic market and export are described below.

4.2.1. Potential and complementarity of renewable energies

Uruguay has excellent potential to install new electricity generation capacity from renewable sources, mainly wind and solar photovoltaic energy. The country has solid combined wind and solar capacities: these energies are complementary on a daily and seasonal basis. This leads to high-capacity factors in the electrolyzer and low hydrogen production costs.

The relevant studies show that the characteristics of solar and wind renewable energies in Uruguay would allow the country to reach levelized costs of energy (LCOE) by 2023, with values ranging between 16 and 19 USD/MWh. Furthermore, the prices of offshore wind energy would vary between 26 and 28 USD/MWh.

The downward cost trend would remain the same over time (although its decline would slow down), driven by Capex reductions and technological improvements. This would allow Uruguay to reach costs of up to 11 USD/MWh in 2040 for using solar resources through photovoltaic technology, 15 USD/MWh for wind resources and 21 USD/MWh for offshore wind resources. These values could vary in more conservative scenarios, depending on variables related to the international context (raw materials and technological development) and other associated country costs.

The studies conducted identify regions in Uruguay with different potential for producing renewable energies (levels I and II). The most promising regions (capacity factors between 25% and 28%) for solar photovoltaic energy (level I) are located in the west of the country, in the departments of Artigas, Salto, Paysandú, Río Negro, Soriano, and Colonia. The area available for level I solar photovoltaic plants has an associated capacity of 60 GW. The central areas (between Rivera and Canelones) have medium-quality resources (level II, with capacity factors between 20% and 24%), with a potential of 135 additional GW.

Additionally, Uruguay has a capacity of 30 GW in high-quality areas for onshore wind power plants (level I, with winds of 8–9 m/s) located on the border between Rivera, Tacuarembó, and Salto, and between Lavalleja, Florida, and Treinta y Tres. The rest of the territory has medium-quality characteristics (level II, with winds of 7–8 m/s) and would allow for an additional generation capacity of 50 GW (McKinsey & Company, 2021).

The area available for offshore development would enable the installation of an additional 275 GW of capacity (World Bank, 2020).

The costs shown below reflect the range of level I – level II resources.

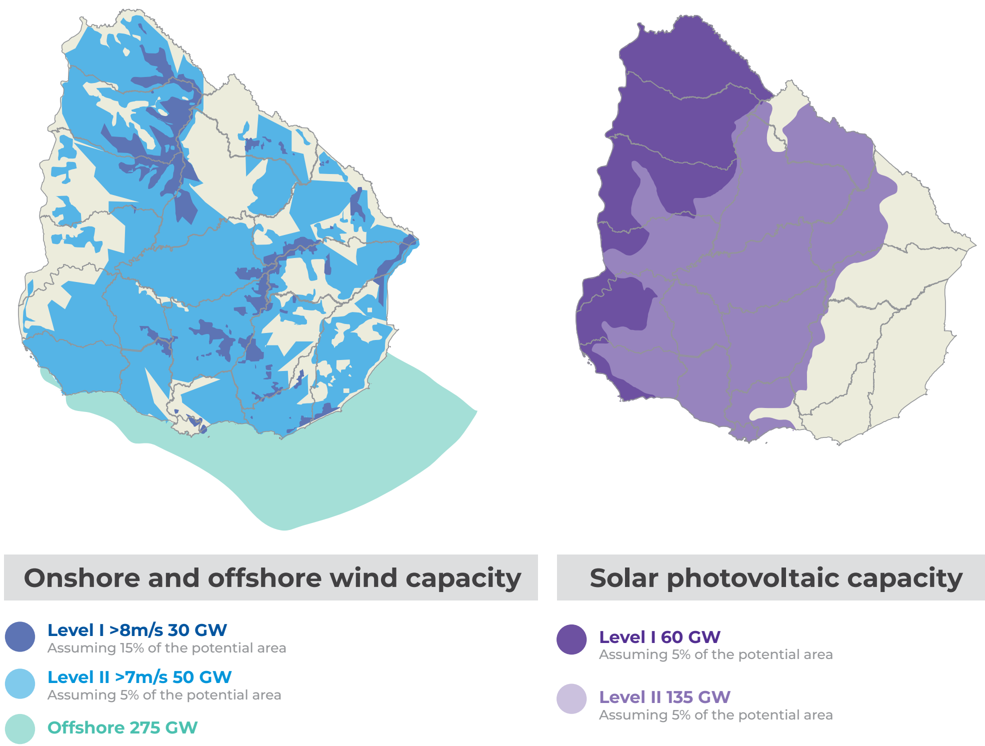


Figure 3a Potential capacity (GW) by renewable source.
Source: Atlas Solar, MIEM, McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

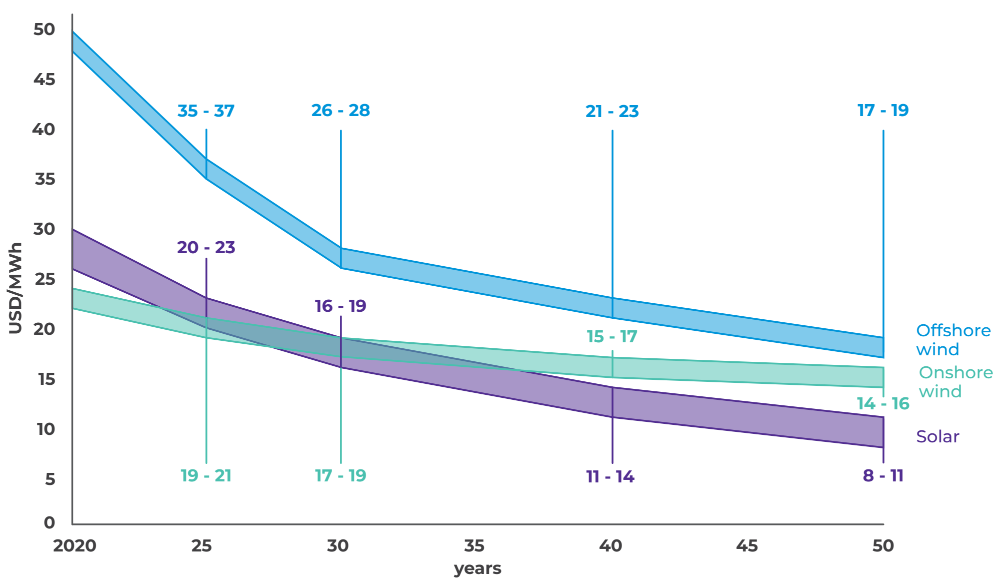


Figure 3b: Levelized cost of energy (based on 5% WACC, not including transportation costs) at scale (+500 MW), USD/MWh.
Source: Adapted from McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

4.2.2. . Electricity matrix with very high renewable energy participation

Some industrial processes need to operate continuously (e.g., one of the possible processes for e-jet fuel production). Their connection to the national electricity grid, with over 90% renewable energies—as mentioned above—positively impacts the profitability of the investments required for producing green hydrogen and derivatives (wind and solar photovoltaic plants supplemented with hydropower and biomass). In these cases, the benefits of a grid connection could be reflected in a 5–10% decrease in the cost of hydrogen compared to an investment solely from off-grid wind and solar photovoltaic facilities with hydrogen storage.

4.2.3. Water availability

Water is used for many activities around Uruguay, ranging from human consumption to food production for domestic consumption and export, other industrial uses, tourism, and energy production.

The current uses authorized by DINAGUA for all nationwide activities amounted to 4.4 million m^3 in 2022. The water requirements to supply the production of green hydrogen and derivatives in Uruguay were estimated to be an additional water demand of less than 1% of the total license currently granted. As with any other activity, green hydrogen projects must be evaluated in terms of water consumption and on a spatial and temporal scale, considering other existing uses in the basin and the development projections for a given region.

A strategy must be in place for developing a socio-environmentally sustainable hydrogen economy in Uruguay. To this end, specific studies will be conducted to obtain accurate information on water use in the sector.

The following image shows the potential water consumption identified for implementing this Roadmap for Green Hydrogen and Derivatives to 2040 and the volume of water allocated by DINAGUA nationwide by year. The figure shows the total number of authorizations granted by DINAGUA, including surface water, groundwater, and reservoirs for different uses.

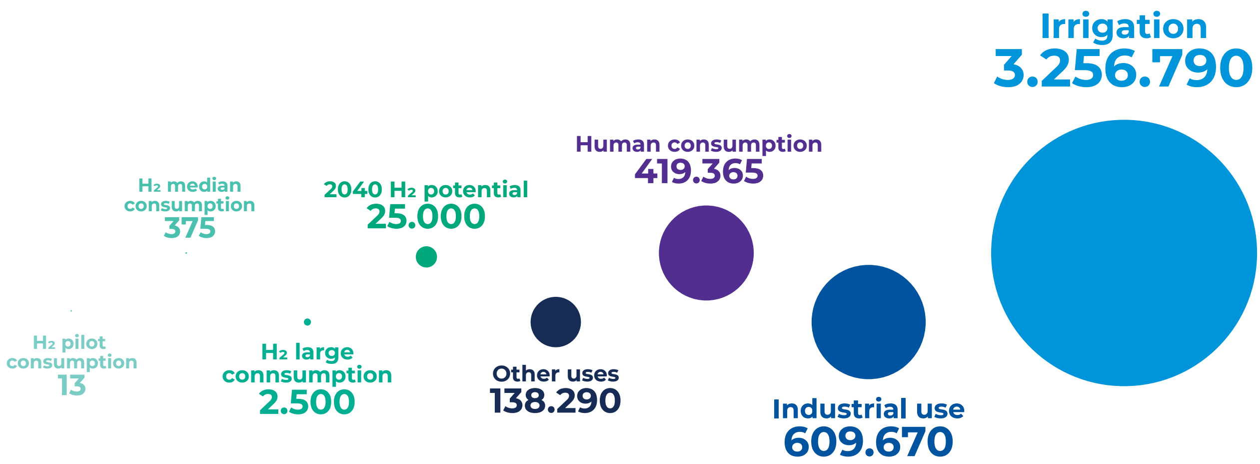


Figure 4: Water consumption authorized by DINAGUA Uruguay; comparison with H_2 projects and Roadmap potential (thousands of m^3/year).

Source: DINAGUA's Hydrological Observatory – 2022 Data.

4.2.4. Biogenic CO_2 availability

Uruguay has biogenic CO_2 available from industrial facilities that use biomass to produce energy. This biogenic CO_2 can be used for producing raw materials, fuels, and green fertilizers. The biomass source can vary: rice husks, sugar cane bagasse or forest waste, as well as fermentation processes during biofuel production, among others.

Studies[3] showed that the estimated CO_2 emissions for 2024 that could be used for producing hydrogen derivatives is approximately 11 million tons of biogenic CO_2 emissions.

The industrial plants that produce this source of biogenic CO_2 are located near areas with good availability of renewable resources, which is important for producing H_2 derivatives.

When determining the potential of producing H_2 derivatives, we considered that the three existing cellulose pulp production plants and the smaller scale energy production plants could provide the amount of biogenic CO_2 necessary for the projected production of H_2 derivatives.

We must note that national forest biomass production is sustainable.[4] Uruguay is very well positioned in terms of sustainable development certifications in forestry production. In Uruguay, 80% of the forest plantations and 100% of the industrially processed products in this sector are certified (Sociedad de Productores Forestales del Uruguay, 2022). Bioenergy has become one of the primary energy sources in Uruguay based, among other things, on the development of the forestry sector, particularly on the industry associated with this productive chain. This sector is expected to complement the economy of hydrogen and its derivatives synergistically.

3 Mercados Energéticos Consultores S.A. (GME) – "Análisis de la disponibilidad de CO_2 para la producción de derivados de H_2 verde en Uruguay" (Analysis of CO_2 availability for the production of green H_2 derivatives in Uruguay). International PtX Hub – GIZ, September 2023).

4 As a result of a State policy supported by all the political parties in office since 1987 to date, Uruguay has promoted the development of sustainable forestry.

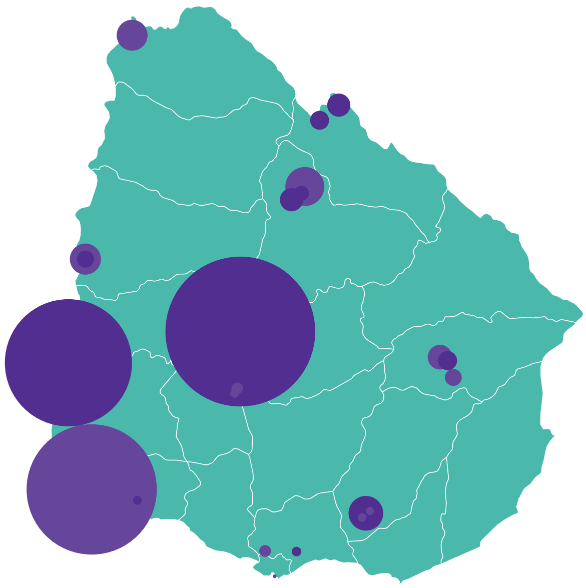


Figure 5: Nationwide availability of industrial biogenic CO_2 from different sources (biofuel plants, electricity generation, food, cellulose pulp, and cement plants).

Source: Mercados Energéticos Consultores S.A. (GME) – Planta Piloto de Ingeniería Química (PALPIQUI). Consultancy: "Análisis de la disponibilidad de CO_2 para la producción de derivados de H_2 verde en Uruguay" (Analysis of CO_2 availability for the production of green H_2 derivatives in Uruguay). International PtX Hub – GIZ, September 2023.

4.2.5. Logistics

Uruguay has access to the Atlantic Ocean and the port of Montevideo, which entails an opportunity for developing the export of hydrogen derivatives such as fuels, raw materials, and low-emission fertilizers.

The country has land routes throughout its territory and domestic transport infrastructure for hydrogen and its derivatives.

It must be noted that the Central Railway will connect the area with the most significant renewable energy potential with the port of Montevideo, providing excellent opportunities for transporting hydrogen derivatives and facilitating their export. Uruguay also has river and road transportation that can help improve competitiveness in transporting exports.

Some background information about the energy sector: in the past decade, Uruguay faced and overcame multiple logistical challenges associated with building generation infrastructure, large industrial plants and transmission works, among others. As an indicator, 60% of the special cargo (either by dimension or weight) transported in the country in 2014 was related to renewable energy projects.

4.2.6. A country to invest in

Uruguay has a strong institutional framework and a profound sense of republicanism and respect for the rule of law. It ranks first in Latin America in rule of law (World Justice Project, 2021) and in full democracy (Economist Intelligence Unit, 2021).

Uruguay is open to national and international private investment, with clear and stable rules, and is a reliable destination for doing business in one of the most economically attractive regions in the world. Additionally, it is a social and politically stable country: it ranks sixth in the world in terms of civil and political liberties (Freedom House, 2022), and leads the region in terms of low perception of corruption (Transparency International, 2022).

Furthermore, it has made considerable progress in digitizing the public sector, ranking 26th in the e-Government Development Index, and was the region's leader in 2020 (United Nations, e-Government Development Index, 2022). It has been awarded investment grade by the main international rating agencies (Standard & Poor's, Fitch Ratings, DBRS, and Moody's), and has demonstrated sustained growth in its Gross Domestic Product (GDP) over the last few years, with the exception of the drop in 2020, related to the COVID-19 pandemic that affected the world.

Uruguay is among the world's leading economies in sustainable investment, according to the ESG Index prepared by JP Morgan. This considers the quality of governance and social and environmental factors. JP Morgan takes the Environmental, Social and Governance (ESG) factors to weigh the country risk indicator. This makes Uruguay one of the most reliable emerging economies to invest in (see figure 7).

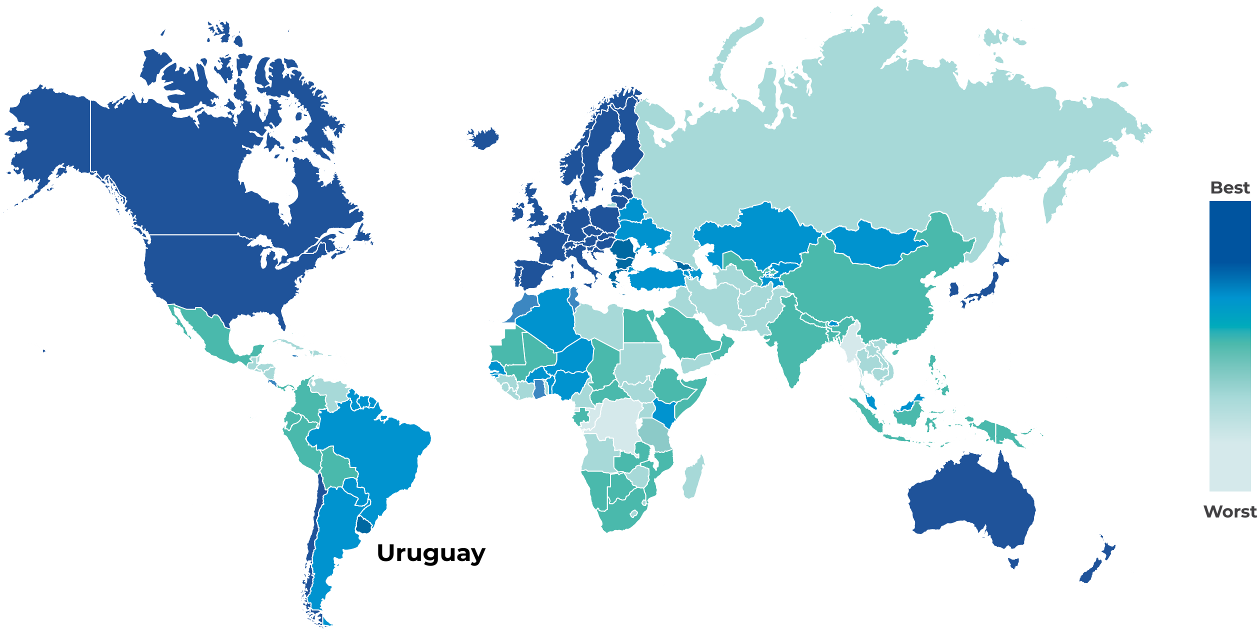


Figure 6: ESG factors performance map. Environment, social and governance. Year 2020.
Source: Uruguay XXI (JP Morgan Bluebay Asset Management - Verisk Maplecroft).

4.3 Regulatory framework in Uruguay for sustainable resource management

Responsible and sustainable management under a robust institutional and regulatory framework is necessary for hydrogen and any other project involving natural resources.

Article 47 of the Constitution of Uruguay declares that environmental protection is of general interest and that integrated water resources management requires participatory processes. This mandate guided the creation of the National Water Policy (Law 18.610 of 2009). The country has also had environmental regulations for many years—with a Water Code since 1978—and an environmental assessment process to authorize new projects since 1994. The Regulations of the Environmental Impact Assessment Law (Decree No. 349/005 and amendments) establish which projects require environmental permits and what type of permits must be applied, including green hydrogen and derivatives.

Access to drinking water is considered a fundamental human right in Uruguay. Water is public, and there is currently no charge for using it. The water code allows charging for water use, but this has not been implemented to date. The guidelines for integrated water management are established in the National Water Plan. They are followed by the basin plans, which show objectives, programs, and projects with short-, medium-, and long-term goals that various institutions develop. Water development works such as reservoirs, tanks, mains, and wells, among others, must have a right of use registered and authorized by the National Water Directorate of the Ministry of the Environment (DINAGUA). There are processes and criteria in place for granting water use rights, considering the availability in the basin and other water use rights previously granted, to preserve the hydrological regime and limit the risk of failures due to variability.

In addition, water extraction over 500 l/s, reservoirs that store volumes of water greater than 2,000,000 m^3 or whose surface area exceeds 100 ha, and wells extracting over 50 l/s must undergo an environmental impact assessment and require a prior environmental authorization issued by the Ministry of the Environment's DINACEA (Decree 349/05).

Uruguay has had an Environmental Protection Law since 2000. This framework includes regulations on effluents, waste, and atmospheric emissions, among others, as well as several national plans and policies.

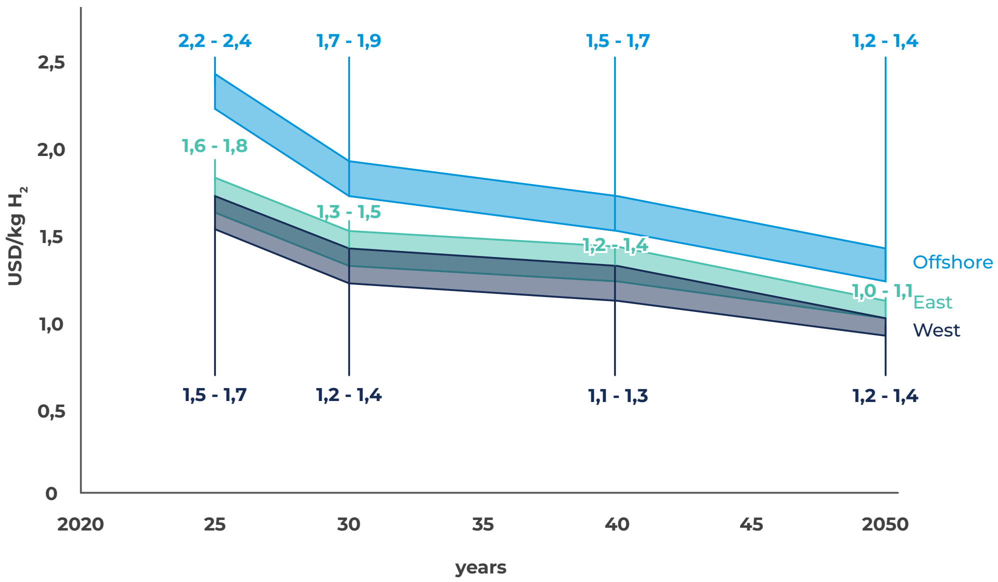
Finally, in 2008, the Land Use and Sustainable Development Law was passed. The law regulates and organizes land use and is implemented locally by departmental governments and municipalities. In 2020, the Ministry of Environment was created to prioritize environmental issues in the public policy agenda.

5.
Production of green hydrogen and derivatives

5. **PRODUCTION OF GREEN HYDROGEN AND DERIVATIVES**

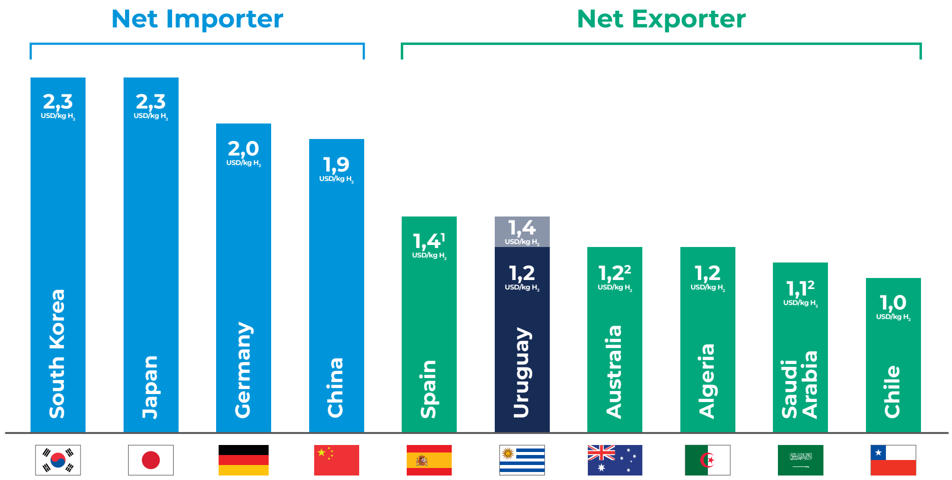
The estimated cost of renewables for 2030 would allow Uruguay to reach green hydrogen production values (LCOH) between 1.2 and 1.4 USD/kgH₂ in the western region and between 1.3 and 1.5 USD/kgH₂ in the eastern region, at a scale of over 500 MW. These production costs would make Uruguay a strong competitor as an exporter of hydrogen derivatives.

The estimated costs of green hydrogen production in different areas of the country (East, West and offshore) can be seen below.



Estimates for a minimum daily production of 250 tons of H_2 including energy and electrolysis (CAPEX, OPEX, inc. water). Storage, transportation, or transmission add 0.3 to 0.5 USD/KgH₂.

Figure 7a: Hydrogen production cost curve by region in Uruguay, USD/kg H_2.
Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.



1. Benchmark taken from the HyDeal announcement for production costs at scale; it excludes transportation and distribution costs.

2. Benchmark taken from Hydrogen Council projections; it excludes transportation and distribution costs.

Figure 7b: Comparison of production costs 2030 (WACC: Chile 6%, Austria 5.4%, Saudi Arabia 5.3%, Spain 5%) (USD/kg H_2).
Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

It is necessary to add logistics costs to the hydrogen production costs. Logistics costs include electricity transmission and hydrogen transportation storage, depending on the configuration and considering downstream hydrogen use needs. Local hydrogen transportation and storage by pipeline would be one of the most financially attractive options for projects larger than 500 MW in scale. The cost of local transport and storage ranges between 0.3 and 0.5 USD/kgH_2. In these cases, the electrolysis plants would be next to the renewable energy generation plants.

Developing the necessary infrastructure and implementing it in a coordinated manner would create synergies, leading to a 4%–6% reduction in LCOH. This considers that hydrogen pipelines, power transmission, or port adaptations are used for several projects rather than each project developing its infrastructure.

Regarding derivatives, the production costs of green e-methanol and e-jet fuel could reach USD 465/t and USD 1,205/t, respectively, considering industrial sources for biogenic CO_2. The competitiveness of these products compared to those of fossil origin lies in the application of CO_2 taxes in importing countries and in the creation of quotas for green products in specific sectors, such as the maritime sector and aviation.

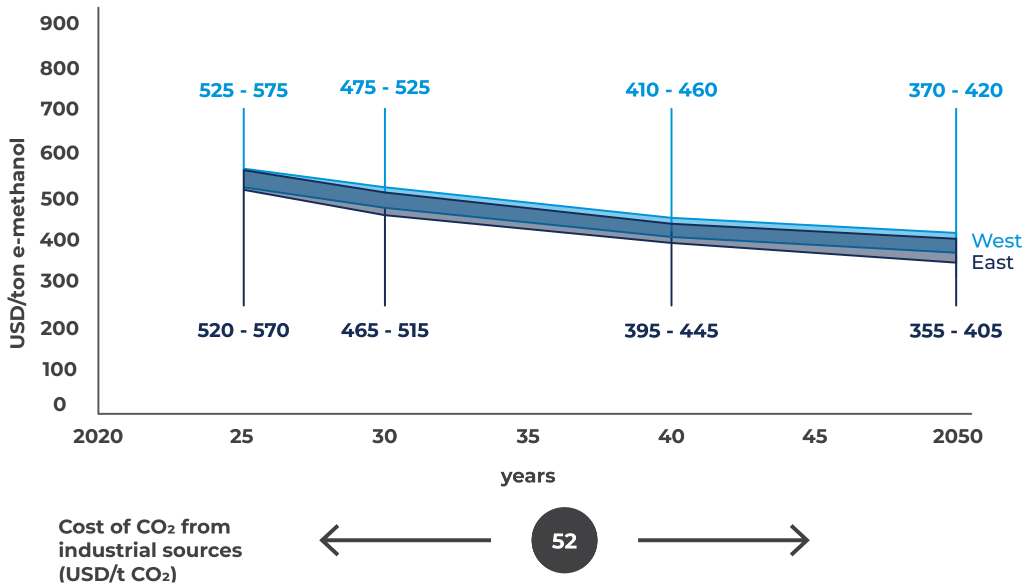


Figure 8a CO_2 supplied industrially: production cost curve for e-methanol, (USD/ton e-methanol).

Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

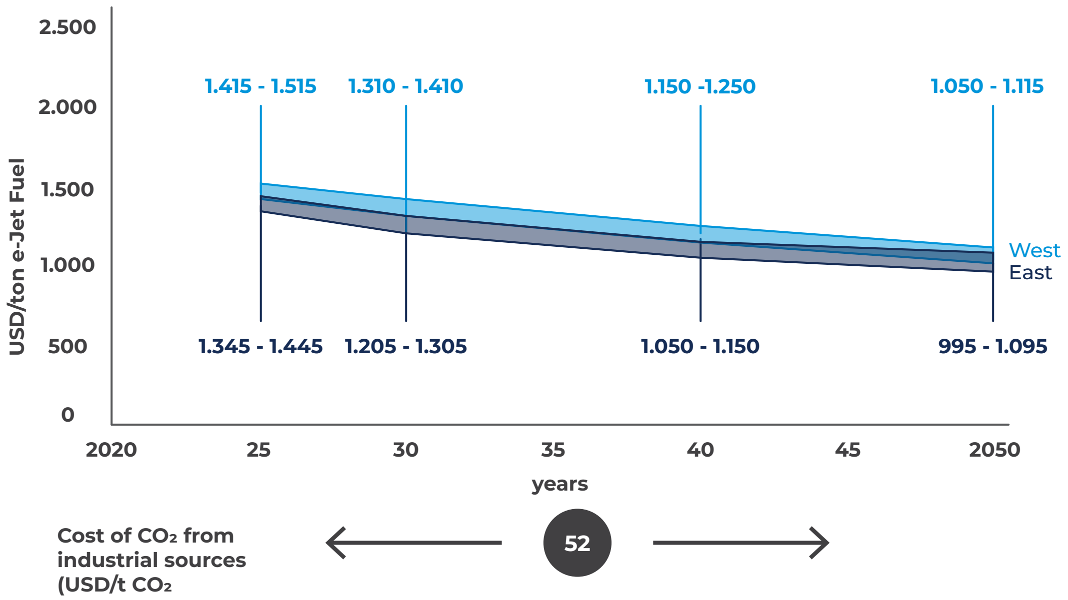


Figure 8b: CO_2 supplied industrially: production cost curve for jet fuel, (USD/ton jet fuel).

Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

6.
Domestic and **export market** potential

6. DOMESTIC AND EXPORT MARKET POTENTIAL

Uruguay has a strong potential as an export market because it stands out for its competitiveness in producing green fuels and raw materials that will reduce the impact of climate change caused by the industry in general and the shipping and aviation industries in particular. This will allow Uruguay to develop the domestic market, contributing to its defossilization and import substitution in land and sea transportation and fertilizer production.

6.1. Domestic market

The main domestic opportunities for hydrogen development in Uruguay will be driven by cost-competitive applications compared to fossil alternatives or other low-emission applications (e.g., the development of heavy-duty vehicles), by applications affected by decarbonization objectives of various industry sectors (such as the shipping and aviation sectors) and, finally, by applications affected by regulation and local incentives (e.g., the promotion of green fertilizers).

The following aspects are considered to determine the main domestic demand targets for the potential uses.

Maritime transport

Demand for shipping fuels, such as ammonia or low-emission e-methanol, is projected to grow following the announcements of international stakeholders and the decarbonization targets of the International Maritime Organization (IMO). A penetration rate of 1% is estimated for domestic market container vessels by 2030 and 9% is estimated by 2040.

This could position Uruguay's ports in a potential green corridor for the sustainable transport of goods and a hub for the region and contribute to decarbonizing other productive sectors.

Fertilizers

The potential creation of a national fertilizer industry made from renewables is interesting, considering the intensity of the use of fertilizers in our country and the fact that, currently, they are made from fossil fuels.

Preliminary cost estimates still indicate a gap compared to its fossil fuel competitor, which will gradually decrease with technology development and market maturity. These developments could have social, environmental, and economic impacts on Uruguay. Therefore, we must analyze the relevance of specific temporary incentives for the sector.

Transport

The most optimistic scenario estimates a penetration of heavy-duty hydrogen fuel cell vehicles of approximately 3% by 2030 and 35% by 2040. In addition, the green diesel obtained as a byproduct of jet fuel production could be used to replace fossil diesel in traditional combustion engines. This could enhance the energy transition in transportation without changing the vehicle fleet.

In a reference scenario and considering the proposed goals, the development of the domestic market would imply a turnover of approximately USD 60 million in 2030 and of USD 540 million in 2040. By 2030, the opportunity will be driven by land transportation, shipping, and fertilizers. By 2040, the adoption of land and sea transportation applications would grow to an annual turnover of USD 430 million. The demand for green fertilizers would also increase, which might replace imports.

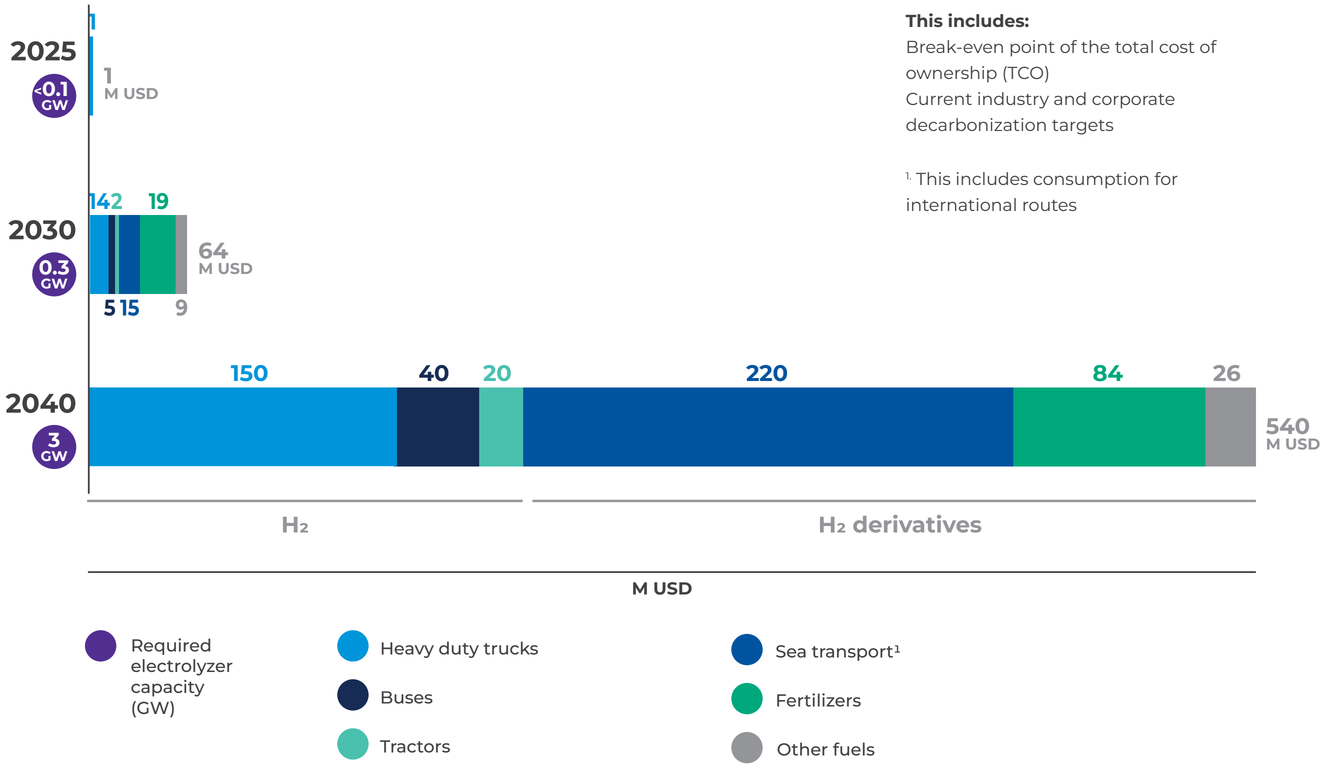


Figure 9: Total domestic demand (including high- and medium-grade heat, airlines [jet fuel], medium-duty trucks, forklifts, and gas blending), USD M.

Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

6.2. **Export market**

The import needs of the main demand centers could be centered in five products. First, there is hydrogen, driven by demand in land transportation applications, as input for industry (e.g., steel and refineries), as well as for electricity and heat generation. The demand from the shipping sector to meet its decarbonization targets drives the production of e-methanol and ammonia (NH_3), the latter also as the primary input for green fertilizers. In addition, e-jet fuel will be essential in driving the aviation sector's regulations regarding Sustainable Aviation Fuel (SAF). Finally, there is Direct Reduced Iron (DRI), given the growing demand for green steel worldwide, where hydrogen is one of the main inputs.

Uruguay's opportunity for exporting green hydrogen and derivatives to the European and US markets will depend on its relative competitiveness vis-à-vis potential competing countries and regions such as the Middle East, Brazil, Chile, and North Africa. This competitiveness may vary according to products and destinations.

E-methanol and jet fuel

Uruguay would have landed costs similar to those of its main competitors thanks to the complementarity of its renewable resources, the use of a decarbonized grid, and access to biogenic CO_2 obtained from industrial and energy processes based on sustainable biomass.

The following products are envisioned for the long term, considering logistical, economic, and safety needs:

Green ammonia

At first, Uruguay would face several challenges regarding production costs and safety issues.

DRI

Uruguay's production costs would align with its main competitors. Given the low global availability of high-quality iron, Uruguay would have a competitive advantage as it produces excellent-quality iron. Its processing would require significant amounts of green hydrogen.

Hydrogen

Uruguay's landed costs (United States and Europe) align with its main competitors. Transportation costs would have a minor impact on landed costs and could eliminate differences in production costs between countries. The competitiveness of exports to Europe would be affected (as for all the other net exporters) if a physical pipeline interconnection from North Africa were implemented to receive hydrogen from the countries of that region.

Based on the levels of competitiveness analyzed, the availability of resources, and considering a more conservative scenario (base scenario), a projected market capture target of 3.5% could be established regarding each product's projected global market volume (see Figure 10).

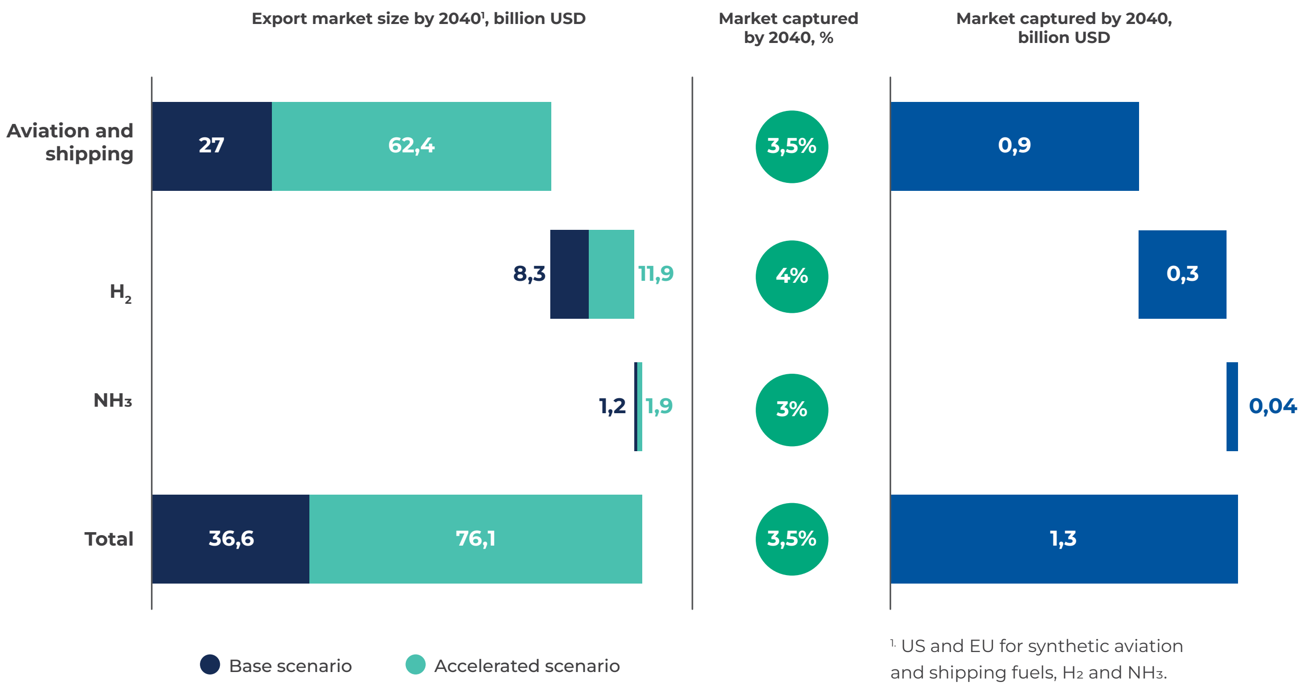


Figure 10: Proposed export market capture for the roadmap.
Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

This means that Uruguay would have an export opportunity of approximately USD 1.3 billion by 2040, and USD 95 million by 2030. E-jet fuel would account for 55% of this opportunity by 2040, while hydrogen would account for 25%, and the shipping sector (ammonia or emethanol), 15% (see Figure 11).

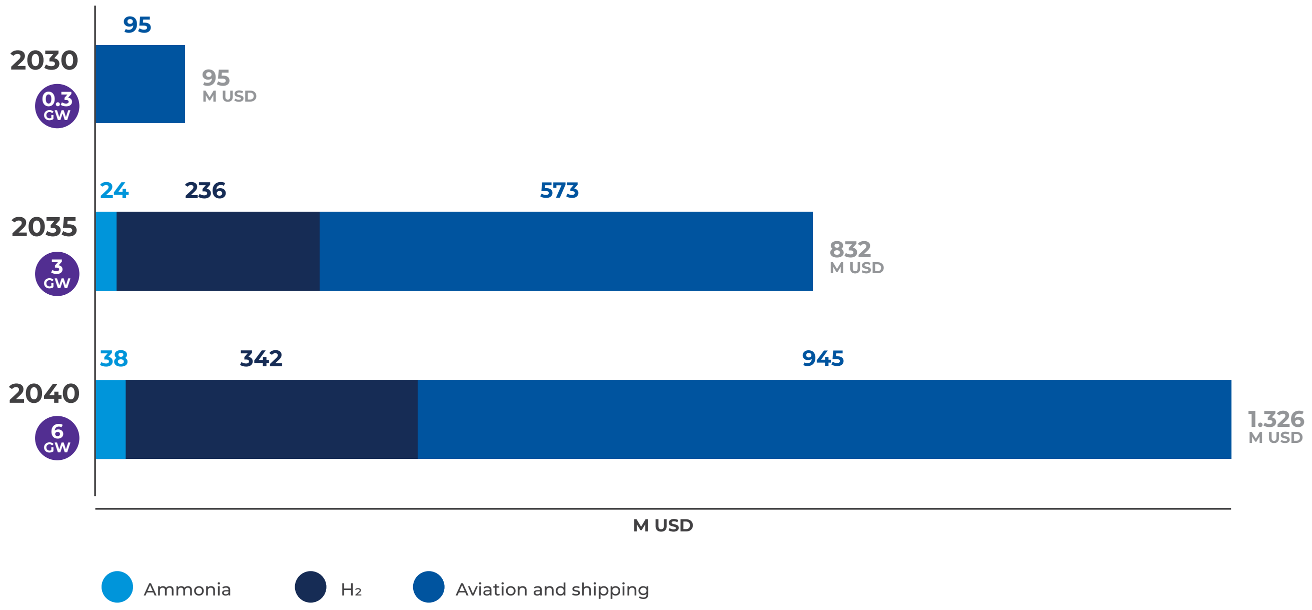


Figure 11: Export opportunity (M USD) to the US and Europe by application.
Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

The exploitation of iron reserves for its transformation into DRI (with green hydrogen) is an additional export opportunity for Uruguay, considering the availability of high-quality ore in the country (concentration level > 67%). This would amount to an additional annual turnover of up to USD 4,100 million by 2040. This will require an additional 5 to 6 GW of electrolyzer capacity and an additional 10 to 12 GW of electricity generation from 2035. This opportunity requires developing port infrastructure in the east of the country and conducting a deeper analysis, and therefore is not included as a target in this roadmap. These targets can be included at a later stage, once the hydrogen-related markets are more mature and the sector is more advanced in Uruguay.

7.

Ambition 2040

7. **AMBITION 2040**

The above competitive advantages show that Uruguay has excellent conditions to develop green fuels, raw materials, and hydrogen-based green fertilizers. This will be a key element to continue implementing sustainable development. This roadmap aims to harness these opportunities given the resources available, the national capabilities, and the existing infrastructure given the maturity of the export markets for H_2 and its derivatives.

The capacities for this new sector are expected to be developed in three phases:

Phase 1

Phase 1, until 2025, will seek to develop the domestic market and lay the groundwork for the first export projects. Progress will be made in implementing specific regulations as the industry develops—engineering for the necessary infrastructure works—and in implementing incentives for the first projects and the next phase. Detailed studies will be conducted to obtain precise information on water and biogenic CO_2 use in this sector.

Uruguay will have to focus on implementing demonstration projects targeting the most relevant applications for the domestic market (e.g., land transport) and attracting the first larger-scale initiatives, focusing on the export market for hydrogen derivatives.

The capabilities required for the future development of this activity will be evaluated, and the existing national supply level will be assessed. A program will be developed with the academia to close the gaps identified.

Mechanisms will be promoted to develop research and innovation based on the Hydrogen Sector Fund launched in 2022. This framework will help build the first pilot projects to produce and use green hydrogen and its derivatives and promote research in this area.

This phase will mark the beginning of the study of the potential for hydrogen production based on offshore wind power as an input for phases 2 and 3.

Uruguay will also analyze the potential contribution to fully decarbonizing its electricity system and how to promote the use of existing infrastructure in our national energy system (both UTE and ANCAP).

Phase 2

From 2026 to 2030, the aim is to scale up the domestic market (demand and projects) and implement the first export-scale projects (such as e-methanol). This will entail analyzing the development of relevant support infrastructure (e.g., pipelines and transmission lines), trying to do so in a planned manner and aiming to optimize nationwide facilities. The incentives will focus on attracting investment through, for example, improving cost competitiveness and stimulating domestic demand, which would help create a new industrial sector, new jobs, and implement import substitution, among other things.

Phase 3

During phase 3, from 2030 onwards, the ambition to 2040 should be confirmed. The development of the domestic market will consolidate in this phase. Defining the logistical or port infrastructure needs, or the offshore production on the Atlantic coast, beforehand could allow further development of the hydrogen value chain and its derivatives. Scaling up towards producing and exporting products such as green hydrogen and green ammonia will be possible.

Roadmap Phases	**Phase 1 (2022 - 2025):** Develop regulation; develop first pilot projects; attract first export-scale projects	**Phase 2 (2026 - 2030):** Domestic expansion; first export-scale projects	**Phase 3 (+2030):** Large-scale domestic market; accelerated export growth
Project overview	+1-2 small-scale projects implementes; medium-scale projects under development	+3-4 medium-scale projects (100-200MW)	+ large-scale projects
Production (energy and hydrogen production)	• 200–400 MW of RES power capacity under development • ~20 MW of H_2 production capacity for small scale and 100–200 MW under development	• 1–2 GW of RES feed-in capacity • Approx. 1 GW of H_2 production capacity	• ~18 GW of RES capacity • ~9 GW of H_2 and derivatives production capacity
Demand (end uses in mobility, industry, and energy)	• +1-2 small-scale projects implemented for transportation (heavy trucks, long distance buses, agricultural vehicles) • +1 project under development; fuels, raw materials, or green fertilizers	• ~1-2 medium-scale projects under development for fuels, raw materials, green fertilizers • + Domestic projects: fertilizers, land and sea transportation	• ~3-4 larger-scale projects under development for exporting, raw materials, green fertilizers, H_2 and NH_3 • + Projects for the domestic market (e.g., transportation, shipping, green fertilizers)
Infraestructure and logistics (pipelines, storage, ports)	• Develop a logistics infrastructure plan on pipelines, transport lines, and ports, promoting synergies • Develop a port solution for exporting fuels, raw materials, or green fertilizers in Montevideo	• Implement the infrastructure plan • Adapting the port of Montevideo to the needs identified in Phase 1	• Continue the implementation of the infrastructure plan
Key mechanisms required: 1 Regulation 2 Incentives 3 Bilateral agreements 4 Social license 5 Capacity building	1 Develop regulations, as well as safety and quality standards. 1 Develop environmental and land-use planning guidelines. 1 Systematize processes for obtaining permits and licenses. 2 Design an incentive structure for investments. Implement financial support for pilot projects. 3 Sign international agreements to promote investment, knowledge generation, pilot implementation and R&D development. 5 Produce knowledge and disseminate information guaranteeing participatory sustainable local development. 5 Coordinate and design capacity building programs for the public, private, and academic sectors.	1 Implement and continue to develop regulations for green hydrogen and derivatives. 2 Implement incentives focused on attracting investment, cost competitiveness, and stimulating domestic demand. 3 Ensure international cooperation along the value chain and the development of projects at scale. 4 Raise awareness nationwide of the potential of green hydrogen and derivatives, considering economic, social, and environmental aspects. 5 Implement capacity building programs for the public, private, and academic sectors.	• Continue identifying and creating mechanisms for the development of green hydrogen and derivatives in the five pillars proposed.

Figure 12: Phases and activities of the H_2 sector roadmap in Uruguay.
Source: (McKinsey & Company, 2021) as per contract #C-RG-T3777-P001 entered into with the IADB.

The domestic market and exports of green hydrogen and derivatives represent an annual turnover opportunity estimated at USD 160 million per year by 2030 and USD 1.9 billion for Uruguay by 2040 (see Figure 13).

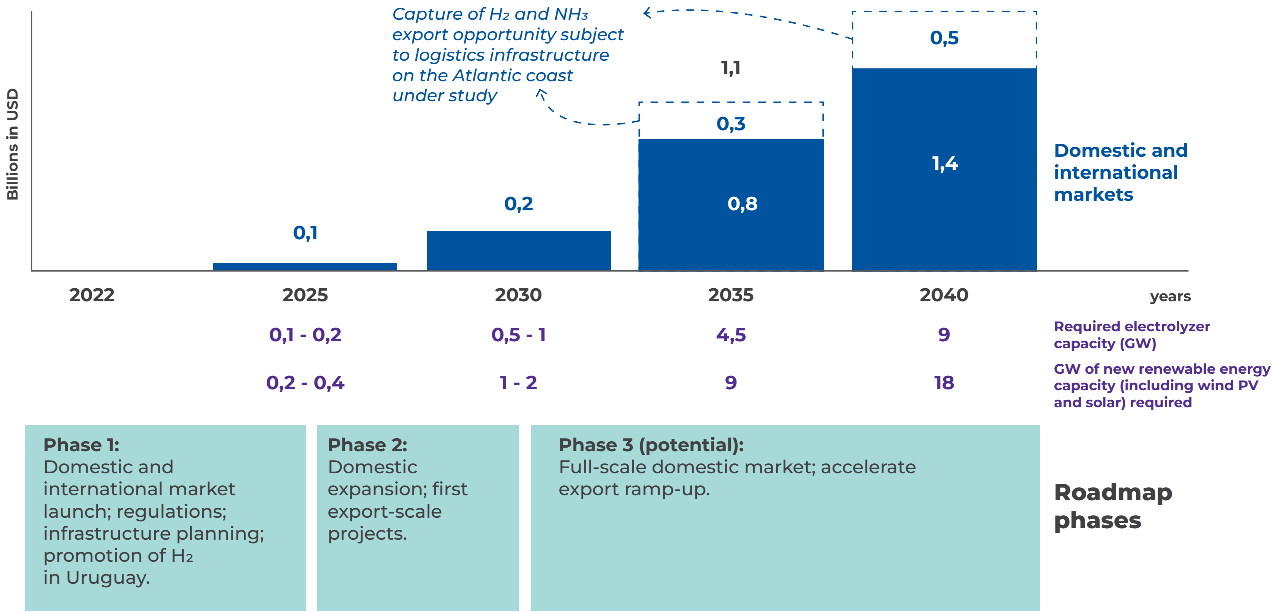


Figure 13: Targets and projections for the Uruguayan hydrogen and derivatives market: 2025-2040.
Source: McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

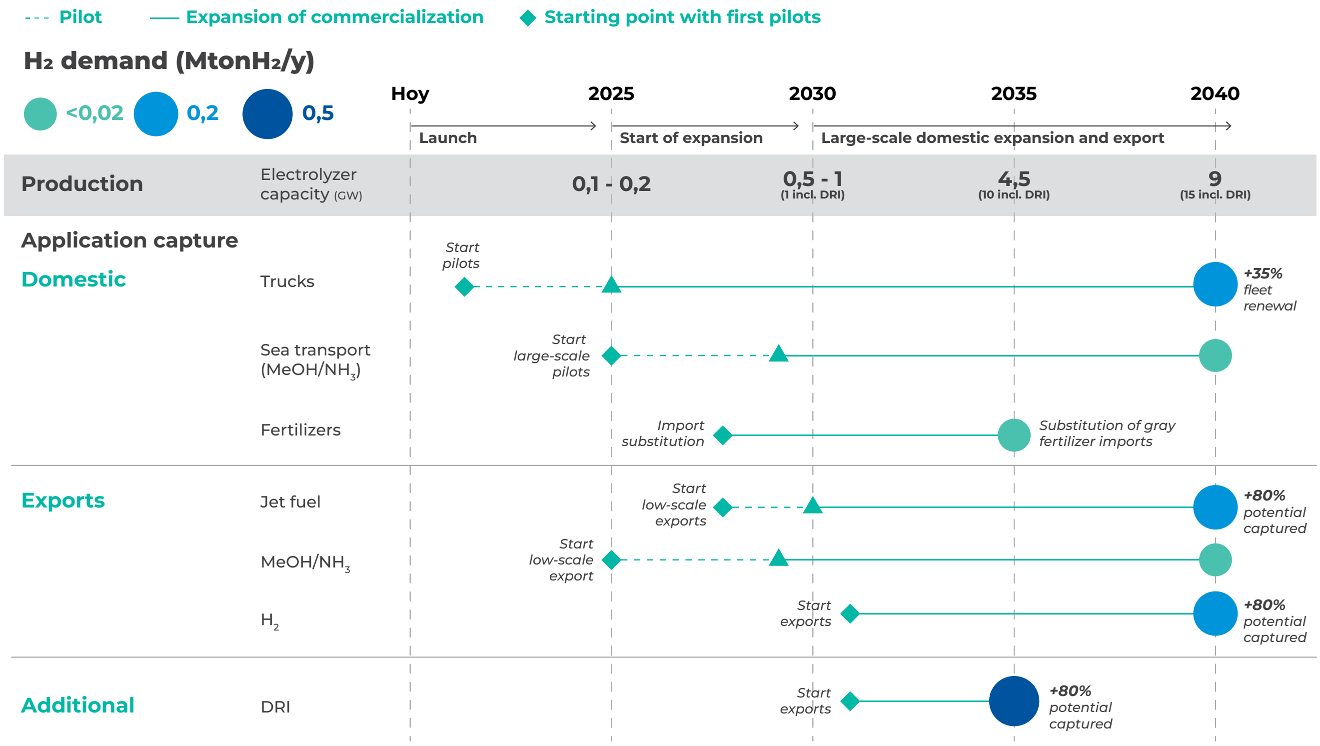


Figure 14: Development schedule.
Source: Adapted from McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

Realizing the aforementioned opportunity of USD 1.9 billion per year implies relevant socioeconomic impacts for Uruguay. In economic terms, the annual turnover of this industry could be similar to the export figures of the country's main agroindustrial products, create over 30,000 direct jobs and eliminate 6 $MtCO_2$ of emissions by 2040 (see Figure 15).

		2030	2040
Building the foundation for the country's long-term growth	Annual turnover in billions of USD	0,2	1,9
	Potential turnover over projected future GDP	+0,3%	+2%
Create +30K skilled jobs: specialized technicians, operators and engineers	Jobs created in thousands	+3	+30
	Total cumulated investment in billions of USD	1,6	18
Eliminate the equivalent of Uruguay's net emissions by 2040	Annual MtonC02 emissions reduced	0,6	6

Figure 15: Socioeconomic and environmental impact of the development of the green hydrogen sector in Uruguay (not including DRI opportunity).

Source: Adapted from McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

This opportunity will diversify Uruguay's productive matrix by increasing value added when including a new industrial link. It will help diversify Uruguay's export offer, opening up possibilities to new markets worldwide. It will also reduce dependence on imported fossil fuels, helping decarbonize other national industrial sectors, and will strengthen the Uruguay's position as a sustainable country.

8.

Potential risks affecting the sector

8. POTENTIAL RISKS AFFECTING THE SECTOR

Some elements to be considered and duly addressed were identified to facilitate the comprehensive and responsible development of green hydrogen and its derivatives. Thirteen main risks have been identified and grouped into four categories.

Risks	Key evaluation metrics
Technological risks	
01 The development and cost reduction of electrolyzers and renewable energy infrastructure is slower than expected. **02** Innovative/alternative technologies (e.g., electric batteries) appear.	Prices of electrolyzers and renewables. Technology reports from international public forums.
Market risks	
03 Slower than expected adoption of decarbonized/green hydrogen products by industry and countries. **04** Lower carbon taxes than expected in the US and the EU. **05** Lower oil/natural gas prices. **06** Increased local production capacity in key markets or competitors.	Regulatory and industry/compliance announcements for target markets. Oil and natural gas prices and projections. H_2-related projects / production capacity announcements by region.
Political/social risks	
07 Low acceptance of new infrastructure. **08** Limiting the application of demand-side incentives (e.g., carbon tax, mandates). **09** Questioning the use of water and its availability for different uses.	Delays versus implementation plan. Public opinion surveys.
Implementation risks/ local competitiveness	
10 Higher than expected country risk for investments. **11** Lower competitiveness of renewables than expected (capacity factors, complementarity). **12** Slower than expected infrastructure implementation. **13** Slower development of the domestic transport ecosystem.	Country risk premium. Operational indicators (capacity, utilization, and cost factors) of the pilots. Fuel cell vehicle penetration/participation.

Figure 17: Mitigation strategies for the six main risks identified based on their probability and impact.

Source: Adapted from McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

There follow six risks with the highest probability of occurrence and impact nationwide, and the mitigation strategies proposed:

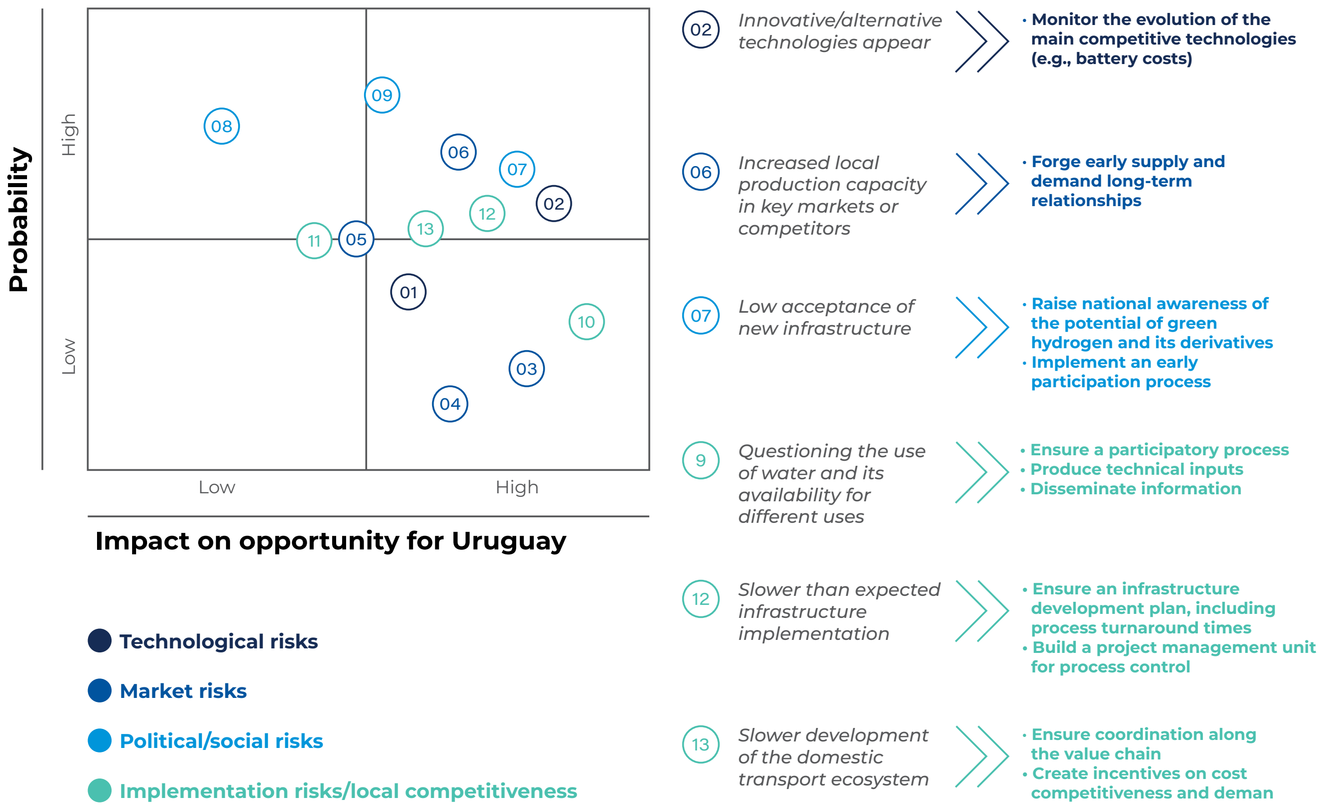


Figure 17: Mitigation strategies for the six main risks identified based on their probability and impact.
Source: Adapted from McKinsey & Company, 2021, as per contract #C-RG-T3777-P001 entered into with the IADB.

The market and the industry's evolution linked to the development of green hydrogen are very dynamic and may impact some projects. It is necessary to develop processes to monitor the evolution of technologies and their costs.

Another risk identified is that of new competitors positioned in key markets and pressuring the supply-side. In this regard, it is essential to create early supply and demand long-term relationships. In addition, not being able to develop the necessary infrastructure in time might impact the industry's development. Uruguay will analyze and propose an infrastructure development plan with the relevant political stakeholders.

9.
Developing a **state policy**

9. DEVELOPING A STATE POLICY

The State will be essential as a coordinator, promoter, and leader for ensuring sustainable and integrated management of the green hydrogen economy in Uruguay. It must efficiently use local resources, promoting dialogue and creating an environment that allows for long-term development that benefits the entire population by adding local value.

The H_2U Program will address various aspects, such as infrastructure, economy, environment, culture and social welfare, in coordination with local governments, non-governmental organizations, companies, academia, and the community.

9.1. H_2U Program

Uruguay is developing the H_2U Program (Presidential Resolution 294/2022) to promote the proposed roadmap. This program aims to ensure comprehensive and sustainable coordination, planning, and articulation throughout the country for developing the economy of hydrogen and its derivatives nationwide.

The green hydrogen interinstitutional group is created. It includes members from seven ministries, the OPP, and eight State organizations and is coordinated by the MIEM.

The program proposes five areas of work to be developed with local governments, non-governmental organizations, companies, academia, and the community.

9.2.1 Capacity building

Local capacity building is essential to enhance the development of green hydrogen and avoid potential gaps between supply and demand in terms of personnel for operational, technical, and engineering areas. Training in renewable energies, particularly hydrogen-related technologies, should be strengthened, adding greater local value.

The greatest needs related to existing and potentially demanded local capacities are related to electrolyzers and the production of derivatives; in this case, it is essential to train more experts.

Gender aspects will be considered to provide equal opportunities and reduce potential existing gaps.

Vocational training and specialization will be enhanced towards higher education focused on hydrogen and its derivatives. A program will be developed in coordination with the National Council for Innovation, Science and Technology (CONICYT) to build scientific and technical capabilities.

The MIEM, ANII, and the LATU created the Green Hydrogen Sector Fund to finance research, innovation, and training projects in this area. In this context, the Government of Uruguay, through ANII, issued an open call to develop the first pilot projects of green hydrogen and derivatives.

In addition, the Energy Sector Fund supports research projects focusing on the hydrogen economy and will also promote other actions, such as the international mobility of researchers to continue promoting academic knowledge.

Programs and actions should continue to be developed to promote national research and innovation in this area.

9.2.2 Regulation

Uruguay has gained experience by incorporating renewable energies and other large-scale projects. This has provided the country with the capabilities and mechanisms needed to manage the environmental permits and authorizations required for projects related to green hydrogen and its derivatives. Work will be done to strengthen and enhance these capabilities in the specific H_2-related aspects.

We should highlight the powers granted to the Energy and Water Services Regulatory Unit (URSEA) in article 150 of the Rendering of Accounts Law No. 19,996 of 2021, which will regulate the production, storage, and transportation of green hydrogen and its derivatives. Progress has already been made in the safety regulation of this energy vector and its derivatives.

Additionally, progress will be made in managing easements for electricity transmission networks and gas pipelines. It will be necessary to evaluate potential solutions linked to tolls for using energy transmission networks (considering its potential as high renewable energy users).

As progress is made, existing barriers and the need to promote new incentives or regulations will be identified and adjusted to the opportunities and challenges of the sector.

9.2.3 Investments

Green hydrogen and derivatives projects will create investment and innovation to drive nationwide local development.

Critical issues for developing green hydrogen and derivatives, both for local consumption and export, will be considered, particularly those related to creating incentives and other mechanisms to promote local value addition.

Specific incentives are already in place under Law No. 16.906 on Investment Promotion Regime and Industrial and tariff exemptions.

Promoting hydrogen and its derivatives for the local market and export requires greater coordination and cooperation between countries. Partnerships with countries that import hydrogen and derivatives will provide support to address regulatory aspects and human capacity building and help facilitate investment.

It is also essential to seek regional cooperation to promote synergies between countries and harmonize international requirements. Some countries, such as Chile, Colombia, Costa Rica, Brazil, and Argentina, have already launched their roadmaps. It will be imperative to coordinate certification aspects regionally to seek harmonized systems following the possibilities of each country and export market.

9.2.4 Infrastructure

Uruguay has the infrastructure for the first green hydrogen and derivatives projects to operate. In this regard, the port of Montevideo has the potential to develop the export of green fuels, raw materials, and green fertilizers early on in the process. Furthermore, it must be noted that the Central Railway will connect the area with the most significant renewable energy potential with the port of Montevideo, providing excellent opportunities for transporting hydrogen derivatives and facilitating their export. Uruguay also has waterways and highways with access to the entire country connected to the capital's port for local transportation.

Part of the infrastructure to be developed is related to installing new electricity transmission networks, gas pipelines, potential port adaptations, and renewable electricity generation plants.

These aspects will be evaluated and coordinated with the relevant stakeholders to determine the next steps.

The implementation of port infrastructures for ships with deeper drafts or the search for other offshore logistics solutions will be analyzed at the beginning of the second phase of the Roadmap. This will evaluate the most convenient way to export hydrogen, ammonia, and possibly DRI in the long term. Furthermore, Uruguay will analyze the potential conversion process of UTE's thermal power generation plants to replace fossil fuels with green hydrogen fuels, thus contributing to decarbonizing the electric power generation matrix in the country's second energy transformation.

Collaboration with regional countries will be analyzed to enable the export of hydrogen and derivatives produced in their territories through local infrastructure, particularly Uruguayan ports.

Several companies are developing offshore hydrogen production worldwide. Uruguay will study the potential of wind energy in the Atlantic for maritime applications with a long-term view by working with ANCAP and other institutions with maritime competencies.

9.2.5 Citizen dialogue

Transparent and active communication with the public will be promoted, using existing national mechanisms and other specific mechanisms, as necessary. We will seek to develop a strategy that supports citizen dialogue by implementing tools and communication formats that allow people to better understand technology and its benefits at the local level, as well as its contribution to global decarbonization challenges.

We will seek to create spaces to exchange concerns all over Uruguay and address them in future activities.

The population should be informed of the progress made, with particular attention to the stakeholders involved in each case. We will organize periodic communications on the progress of the economy of green hydrogen and its derivatives.

Components	Responsible parties & potential partnerships	Activities
CAPACITY BUILDING	MIEM, national academia: universities, UTU, CONYCIT, ANII, AUCI, among others.	• Identify gaps and roadmap for vocational and technical training • Continuous training • Hydrogen Sector Fund, Energy Sector Fund, call for State-supported projects and research and innovation projects • Partnerships with international cooperation for capacity building and international communication aspects
REGULATION	MIEM, URSEA, MVOT, MTOP, MA	• Safety and quality regulations • Environmental guidelines, water-use studies • Regional certifications • Guidelines for land use and easements for gas pipelines and electric transmission • Actions to monitor technological developments (technological antenna)
INVESTMENTS	MIEM, MEF, MA, MRREE, OPP, Uruguay XXI, UTE, ANCAP, ANDE	• Access to data and information • Tax incentives, support in managing permits and international positioning • Aspects related to the national electricity system • Prospecting and evaluation of green hydrogen production in marine space for potential future development
INFRASTRUCTURE	MIEM, MTOP, MDN, MA, OPP, ANP, ANCAP, UTE	• Port aspects, electricity transmission networks, gas pipelines, use of railroads, river transportation • Studies to identify the best areas in Uruguay for components of the H_2 derivatives value chain • Aspects related to the development of green thermal energy in UTE's thermal generation plants
CITIZEN DIALOGUE	MIEM, MA, civil society.	• Design and implementation of a national communication and citizen participation plan • Produce reliable and accessible information for the population • Regular and transparent communication of progress

10.
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H2U

October 2023