Renewable Hydrogen in Latin America and the Caribbean: Opportunities, Challenges, and Pathways

LAC Green Hydrogen Action

Title:
RENEWABLE HYDROGEN IN LATIN AMERICA AND THE CARIBBEAN: OPPORTUNITIES, CHALLENGES, AND PATHWAYS

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LAC Green Hydrogen Action aims to engage and articulate all the actors involved in green hydrogen in Latin America and the Caribbean through an alliance to encourage the development of the industry to position Latin America and the Caribbean in the global green hydrogen market. The alliance is composed by the Ministry of Environment and Energy of the Government of Costa Rica (MINAE), Alianza por el Hidrógeno Costa Rica, Chilean Hydrogen Association (H2 Chile), Colombian Hydrogen Association (Hidrógeno Colombia), Mexican Hydrogen Association (H2 México), and Peruvian Hydrogen Association (H2 Perú).

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Santiago de Chile, August 2023

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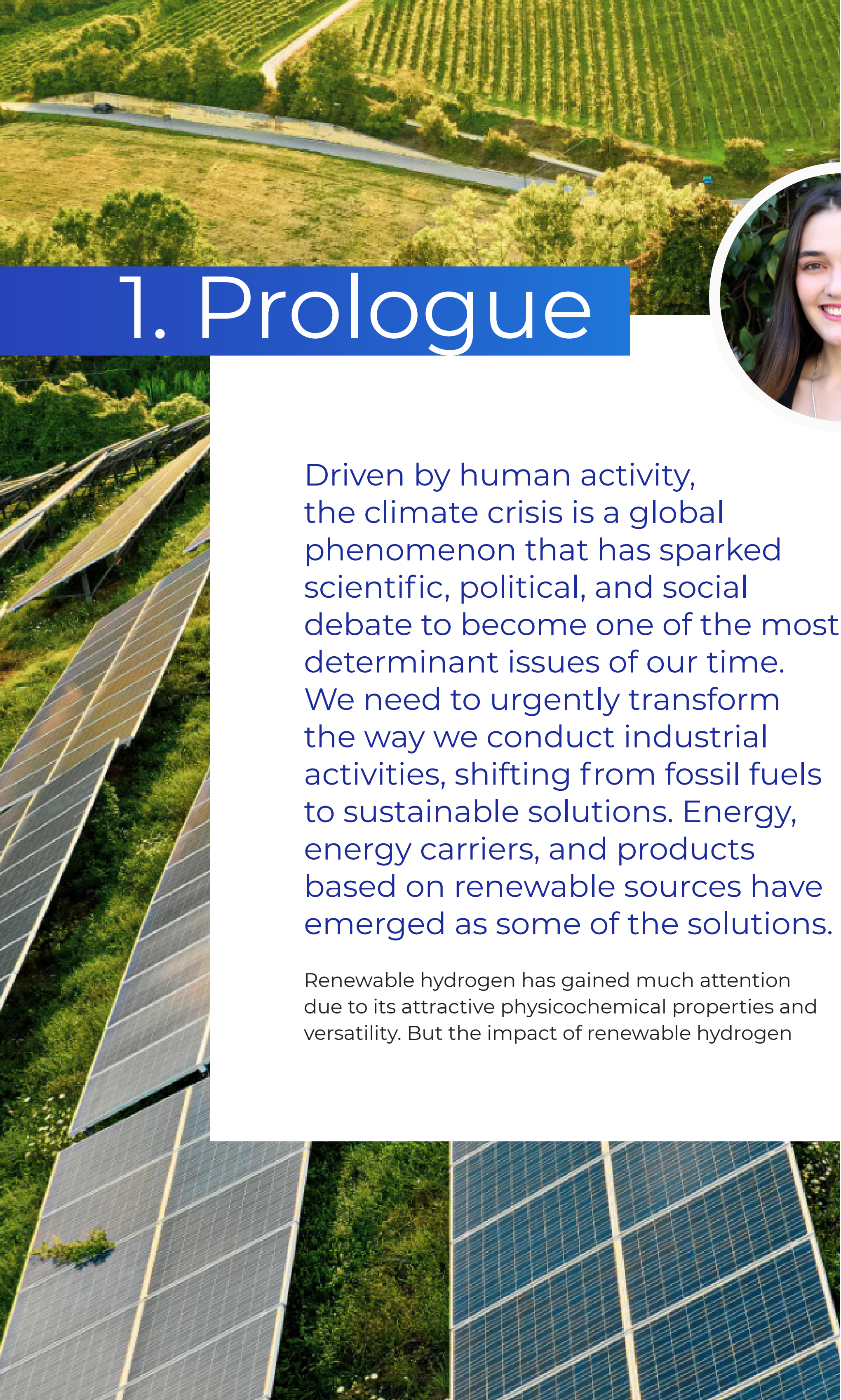


1. Prologue

Isabella Boese, Studies Coordinator, Chilean Hydrogen Association, H2 Chile, Secretary of LAC Green Hydrogen Action.

Driven by human activity, the climate crisis is a global phenomenon that has sparked scientific, political, and social debate to become one of the most determinant issues of our time. We need to urgently transform the way we conduct industrial activities, shifting from fossil fuels to sustainable solutions. Energy, energy carriers, and products based on renewable sources have emerged as some of the solutions.

Renewable hydrogen has gained much attention due to its attractive physicochemical properties and versatility. But the impact of renewable hydrogen goes beyond its production method. It can reshape the energy trade map, where Latin America and the Caribbean can stand out as clean hydrogen powerhouses due to its abundant renewable wind, solar, and hydropower resources in surplus of domestic demands. The region's countries have unveiled ambitious national hydrogen roadmaps and strategies, outlining long-term visions and addressing technological and political challenges.

In the pages that follow, the LAC Green Hydrogen Action alliance explores the renewable hydrogen industry in Latin American and Caribbean countries, analyzing pathways, highlighting opportunities, and discussing the challenges faced by eight nations – Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay, where we identified over 140 hydrogen projects in different stages of development. While the private sector plays a significant role in promoting the region through these projects, the public sector has awakened to renewable hydrogen's potential to achieve decarbonization and catalyze growth.

Yet challenges abound. The path to success hinges on critical policy decisions in the coming years, carefully weighing the interests of market stakeholders and crafting robust regulatory frameworks in harmony with local needs. Moreover, the high investment risks and absence of offtakers delay and even threaten achievement of final investment decisions.

So far, public-private cooperation has contributed to advancing the development of national hydrogen industries. Thus, each country has, in general, moved ahead on its own. However, discussions at a public and multinational level are also required.

The climate crisis transcends national borders. Thus, we need to recognize our shared responsibility for the planet and future generations and jointly contribute with innovative, sustainable, and optimal solutions to minimize and manage the effects of global warming. This study is one of the multiple calls to reinforce collaboration.

Marcos Kulka

Executive Director,
Chilean Hydrogen Association,
H2 Chile.

"We must establish partnerships and join forces among the multiple stakeholders to promote renewable hydrogen and its derivatives within our society and industries. This entails both public-private cooperation and cooperation within the private sector. The Chilean Hydrogen Association's strategic pillars include the forging of alliances that enable knowledge-sharing, technology transfer, and debate on standards and regulations to promote the development and adoption of hydrogen as a clean energy carrier. This study is a concrete achievement of regional cooperation to deliver critical insights into the current hydrogen industry and its prospects. H2 Chile is proud to have the Secretariat of the LAC Green Hydrogen Action Alliance for the second year running in 2023 and will continue to cooperate with its peers to achieve the sustainable vision we all aspire to".

Mónica Gasca

Executive Director,
Colombian Hydrogen Association,
Hidrógeno Colombia.

"Colombia has incredible renewable energy, wind, solar and hydroelectric resources. Furthermore, it is strategically located to promote a hydrogen economy with Europe and Asia. Through the Colombian Hydrogen Association, over 40 companies are working together to consolidate the hydrogen ecosystem, developing strategies with the government to address financing, knowledge, local demand incentives, and international cooperation. The LAC Green Hydrogen alliance is key to sharing the lessons learned and promoting a regional market that helps LATAM position itself as an exporter of clean hydrogen to power zero-emission economies".

Flora Montealegre

Representative of Alianza por el Hidrógeno, and Executive Director
Fundación CRUSA.

"As a representative of the Costa Rican Hydrogen Alliance, we stand filled with pride to see the great progress made in this and other Latin American countries to promote development of green hydrogen as a vector for the decarbonization of our economies. In recent years, many stakeholders have shown rising interest and joined our Alliance, recognizing the great potential for these technologies to generate new growth opportunities while creating environmentally and socially sustainable value. We will continue supporting this cause, promoting the inclusion of key partners, and finding ways to advance new initiatives together—all as part of our commitment to promote a more prosperous, sustainable, and inclusive future for generations to come".

Israel Hurtado

Executive President,
Mexican Hydrogen Association,
H2 México.

"Hydrogen has become a pivotal force to achieve our carbon neutrality goals and drive a sustainable energy transition. Latin America and the Caribbean, with abundant renewable resources, hold immense potential for large-scale competitive renewable hydrogen projects. Despite the challenges, embracing renewable hydrogen is vital to reduce emissions and combat climate change. We must adopt environmentally friendly production methods to explore hydrogen's multifaceted applications. As representatives of the energy industry, we must seize this unprecedented opportunity to shape a greener future. This document sheds light on our region's potential, empowering us to make informed decisions for a sustainable and prosperous energy landscape for generations to come".

H2 México
ASOCIACIÓN MEXICANA DE HIDRÓGENO

Daniel Cámac

President,
Peruvian Hydrogen Association,
H2 Perú.

"H2 Peru applauds the release of this important report, which provides a first glimpse of Latin America's potential to position itself as a key macro-region for global decarbonization through the production, adoption, and export of hydrogen and its derivatives. The collaborative work between hydrogen associations in the region through LAC Green Hydrogen Action is a testament to the importance of generating a shared perspective on the energy transition. H2 Peru participates in this coalition based on the values of cooperation and solidarity and will seek to contribute to this great mission of creating a sustainable hydrogen industry in Latin America".

H2 PERÚ
Asociación Peruana de Hidrógeno

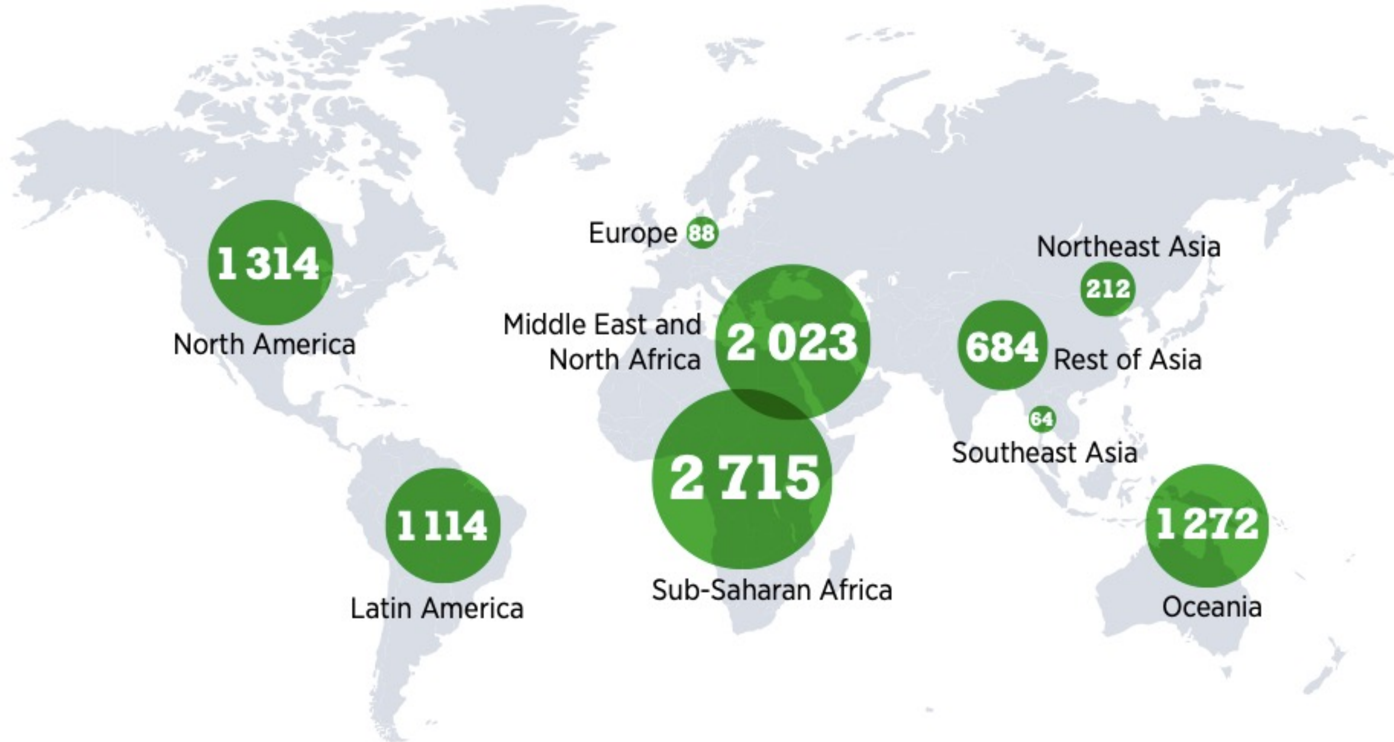
2. Introduction

In recent years, hydrogen (H2) has emerged as a crucial element to achieving national carbon neutrality targets and making the energy transition by the middle of this century. Its growing prominence is due to its attractive energy properties and ability to unlock sustainable opportunities, replacing coal, natural gas, and oil. Moreover, the costs of renewables and electrolyzers are falling, making renewable hydrogen (RH2) an economically feasible technology in the near term.

Along with creating a new energy market, hydrogen will reshape the energy trade geography and consolidate regional energy relations [1]. Many countries have announced or published national hydrogen roadmaps or strategies, relevant to establishing long-term visions regarding hydrogen's role in the energy sector and identifying both the technological and political potential, as well as the challenges [2]. In addition, over 30 countries have included import or export plans in their strategies, indicating that cross-border trade will follow. While the European Union is likely to become a key import market, Africa, the Americas, the Middle East, and Oceania are regions with the technical potential to emerge as major clean hydrogen producers and exporters (Figure 1) [1].

Most Latin American and Caribbean countries have high renewable potential. The quality and abundance of renewable resources (wind and solar), combined with available space and access to water, facilitates the deployment of large-scale competitive renewable hydrogen projects. Thus, renewable hydrogen could be produced for local use and surpluses exported. This would be strengthened by some Latin American and Caribbean countries' strategic locations for trade and transit hubs.

However, Latin America and the Caribbean face distinct regional challenges that must be addressed for the sustainable development of the hydrogen market. Success will depend on crucial policy decisions made in the coming years, including the balance of interests of energy market stakeholders and the creation of regulatory frameworks aligned with the global and regional context and prospects [1-3]. This document aims to deliver an overview of the renewable hydrogen industry in Latin American and Caribbean countries by comparing the nations' pathways, opportunities, and challenges. Eight countries are reviewed: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay. This study seeks to contribute to updating regional advances, promoting awareness of its potential, and stimulating the hydrogen industry.



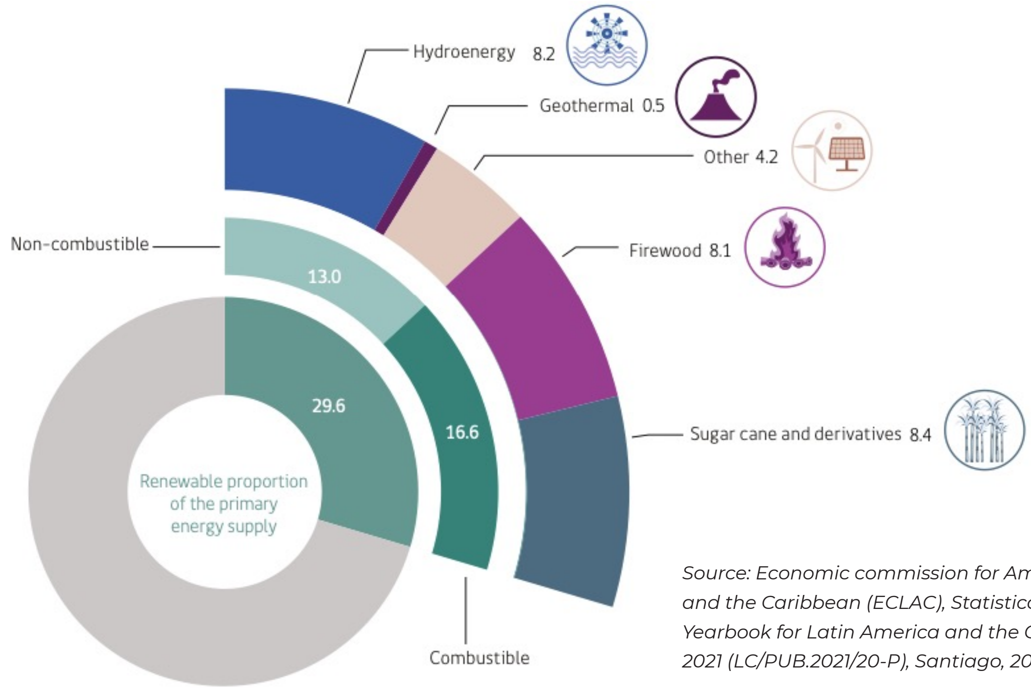
Source: IRENA (fothcoming-a). Map source: Natural Earth, 2021

Figure 1: Technical potential to produce renewable hydrogen for less than USD 1.5/kg by 2050, in EJ [1].

3. Renewable hydrogen in Latin American and Caribbean countries

3.1. Regional energy and hydrogen context

Latin American and Caribbean countries have different levels of industrial development, with activity concentrated in five countries: Argentina, Brazil, Chile, Colombia, and Mexico [2]. In 2019, 70% of the region's primary energy supply was fossil-fuel based, with natural gas accounting for 33%, oil 32%, and coal 5%. The fossil fuel share varies by sector, with 99% in the transport sector and an estimated 55% in the electricity generation sector [4]. According to the Latin American Energy Organization (OLADE), the total share of the renewable primary energy supply in Latin America and the Caribbean is 29.6%. On the one hand, combustible energy sources, which represent 16.6% of the primary energy supply, are mainly attributed to sugarcane and derivates (8.4%) and firewood (8.2%). On the other, non-combustible energy sources account for 13% (Figure 2) [5]. Hydropower is the primary renewable energy source in the region. However, the share of wind and solar energy rose from 4.1% to 14.4% between 2000 and 2019 [4].



Source: Economic commission for America and the Caribbean (ECLAC), Statistical Yearbook for Latin America and the Caribbean, 2021 (LC/PUB.2021/20-P), Santiago, 2021.

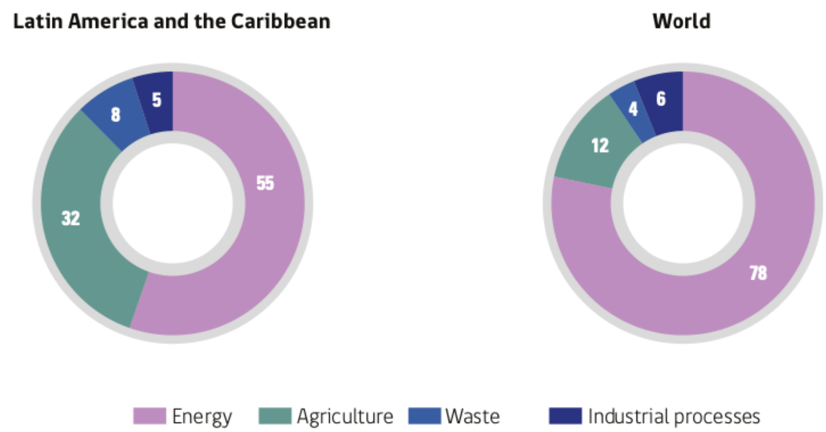
Figure 2: Renewable primary energy supply by energy type in Latin America and the Caribbean (measured in percentages), using data from 2019 [4].

Renewable energy represents almost 100% of the primary energy supply in Costa Rica, El Salvador, Granada, Haiti, and Honduras [5] and represents a significant share in Uruguay (61.1%) and Brazil (48.5%). It is significantly lower in countries such as Chile (33.8%), Peru (25.1%), Argentina (10.3%), Colombia (23.1%), and Mexico (9.6%) [5].

The share of renewables in the electricity matrix ranges from 30% in Mexico to over 95% in Uruguay and Costa Rica [6-8]. While Argentina and Mexico are highly dependent on natural gas for thermoelectric generation [6, 9], hydropower plays an important role in the region, representing over 60% of electricity generation in countries such as Costa Rica and Colombia [2, 8, 10]. However, climate change and the consequential variations in rainfall patterns have undesirable effects on the electricity generation capacity from water resources. Brazil has already experienced this and had to increase the share of natural gas-fired thermoelectric plants to 12.8% in 2021 due to the shortage in rainfall [11].

Latin America and the Caribbean contribute a small share of global greenhouse gas emissions. In 2018, the region emitted 3.179 billion metric tons of carbon dioxide equivalent, approximately 7% of the global total. While 55% of the region's emissions are attributed to the energy sector, another 32% are related to agriculture (Figure 3) [5]. On the one hand, emissions linked to the energy sector are relevant in countries such as Chile, Colombia, Brazil, Mexico, and Argentina [12-15]. On the other, Uruguay and Costa Rica's highly renewable energy matrixes mean most of their emissions are related to the transport sector [2]. For their part, emissions in Peru and Brazil are primarily due to land use changes [11, 16].

Reducing emissions is extremely important, as climate change threatens human and environmental security. Fossil fuels must be replaced if Latin American and Caribbean countries are to align with global climate goals. Most of the countries of interest for this study have publicly pledged to achieve carbon neutrality by 2050, such as Argentina, Brazil, Chile, Colombia. Costa Rica was the first Latin American country to announce a net zero emissions target for 2050, while Chile and Colombia have passed 2050 net-zero goal legislation [17, 18]. In turn, emissions reduction ambitions increased in countries such as Peru and Uruguay, compared to the first national determined contribution. Net-zero pledges for Mexico are under discussion and so far, the country has proposed GHG reductions of up to 35% by 2030 compared to the business-as-usual scenario, which could grow to 40% if external support is secured [19]. Some countries have also recognized the role of hydrogen in achieving these commitments. For example, Chile mentioned that 24% of its emissions reduction would be thanks to renewable hydrogen [12].



Source: Economic commission for America and the Caribbean (ECLAC), Statistical Yearbook for Latin America and the Caribbean, 2021 (LC/PUB.2021/20-P), Santiago, 2021.

Figure 3: Comparison of GHG emissions by sector (measured in percentages) between Latin America and the Caribbean and rest of the world, using data from 2018 [4].

As for the region's hydrogen demand, according to the International Energy Agency, it was 4.1 Mt H2 in 2019, or 5% of the global total, of which 61% was for pure hydrogen (2.5 Mt H2/year) and the rest was for mixed hydrogen (1.6 Mt H2/year) [2]. Hydrogen is mainly used as a feedstock for refineries and the chemical industry [3]. It has also been used to produce ammonia for agricultural fertilizers [2, 3]. Distinctly, Chile has experience in hydrogen use for methanol production, while Peru uses most of its hydrogen demand to produce ammonium nitrate for mining [2]. Argentina is the only country in the region with considerable hydrogen demand for four main current hydrogen applications in the industry, namely ammonia production (33%), oil refining (27%), methanol (15%), and direct-reduced iron (16%). While Chile and Colombia reached demands of 0.2 Mt H2/year, it was almost 0.4 Mt H2/year in Argentina and Brazil. Mexico required even larger amounts of hydrogen, with demand of 0.7 Mt H2/year, and Trinidad and Tobago's hydrogen demand was 1.8 Mt H2/year in 2019 [2].

Hydrogen production to meet the region's hydrogen demand is almost entirely fossil-fuel based. Natural gas is the primary feedstock, accounting for 91% of total production in 2019 and 32.5 Mt of CO2 emissions (2019) [2]. Comparing the countries of interest, the largest producer is Mexico, with 700 kt (2019). A short-term opportunity could be low-carbon hydrogen production from existing fossil fuel infrastructure, but this would require retrofitting production units with carbon capture, utilization, and storage (CCUS) technology [2]. Moreover, blue hydrogen (produced from fossil fuels with CCUS) could follow similar patterns as the gas market and potentially experience import dependencies and market volatility [1]. Lastly, the falling cost of renewable hydrogen means that investment in fossil fuel-based supply chains could become stranded [1].

Water electrolysis for hydrogen production remains limited in Latin America and accounted for less than 0.3% of total hydrogen production in 2019 [2]. As the region has the long-term potential to produce large amounts of low-cost hydrogen from renewable electricity (Figure 4), renewable hydrogen production through electrolysis is expected to increase in the coming years [2, 3]. During that period, the levelized cost of hydrogen (LCOH) via electrolysis could fall below USD 1/kg H2 using a hybrid energy supply (Figure 3) [2]. As key regions are distant from current hydrogen demand hubs, infrastructure is essential for scaling up production.

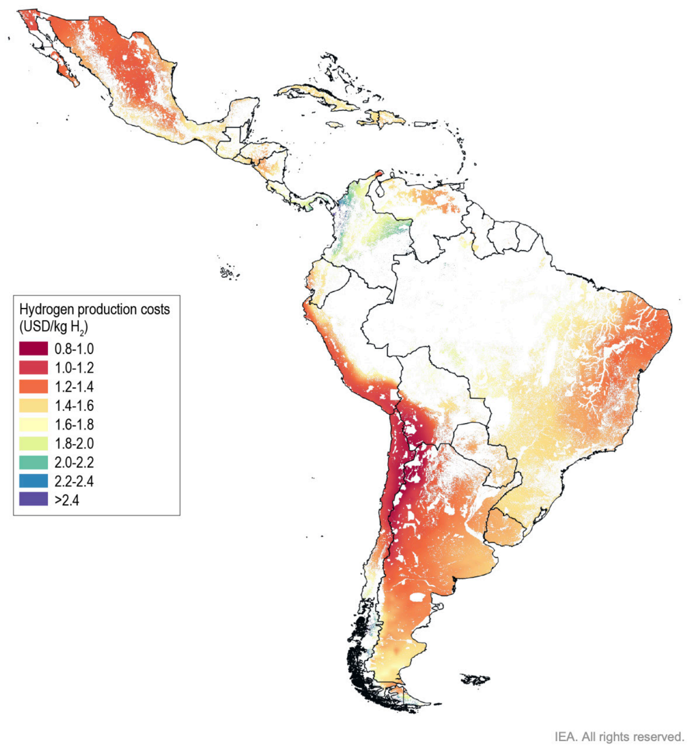


Figure 4: LCOH , Latin America, 2050. Retrieved from IEA (2021) [2].

3.2. Advances in hydrogen policy and regulation

Of the eight countries reviewed, five have public hydrogen policies in the form of a national strategy, roadmap, or plan (Fig. 5). Chile was the first Latin American country to launch a comprehensive strategy in 2020. The primary opportunities include replacing fossil-fuel based hydrogen in refineries and finding new hydrogen applications for long-distance and heavy-duty transport. Moreover, it set the goals of 200 kt RH2 annual production by 2025 and increasing the national electrolyzer capacity to 5 GW by 2025 and 25 GW by 2030 [20]. The strategy is currently accompanied by the 2023-2030 Action Plan, which aims to strengthen the measures and goals with the participation of communities, civil society organizations, academia, and industry [21]. Colombia followed with the publication of a national hydrogen roadmap in September 2021, which defines a production target of at least 50 kt of blue hydrogen by 2030 and a capacity of 1-3 GW of electrolysis by 2030, without making longer-term commitments or setting renewable hydrogen goals [22]. As for Argentina, it launched the 2030 National Low-Emission Hydrogen Strategy, aiming to create a roadmap to promote public-private cooperation, investment in science and technology, and industrial participation. However, no production or capacity goals have been defined [23]. Countries such as Uruguay and Costa Rica seized the momentum and launched their strategy and roadmap in 2022 and 2023, respectively. Costa Rica announced an installed electrolysis capacity target of 150-500 MW by 2030 [24, 25], while Uruguay aims to achieve 1 Mt RH2/year by 2040, increasing electrolysis capacity to 0.1-0.3 GW in 2025, 1-2 GW in 2030, and 10 GW in 2040 [7]. As for Peru and Mexico, neither has published a national policy, though the Peruvian and Mexican Hydrogen Associations have proposed a hydrogen roadmap as guidance [26, 27]. It is worth mentioning that Brazil lacks a consolidated strategy despite its many project announcements [28], though it did publish a technical note [29] and a resolution. The latter establishes the National Hydrogen Program and the program governance structure [30].

Figure 5: Hydrogen policies in American countries [1, 31-35]

Governments are essential to supporting industry investment and creating a regulatory framework that can assist hydrogen project development. Unfortunately, Latin America lacks specific regulations for hydrogen, which is generally considers a chemical element and hazardous substance rather than a fuel or energy carrier [3, 36]. Moreover, the existing regulatory framework is insufficient, generic, or outdated and fails to recognize the renewable value chain or potential uses [3, 37].

Argentina has had a hydrogen promotion law (Law 26.123) since 2006 [2], which regulates hydrogen as a fuel but only states in general terms that it "promotes research, development, production, and use of hydrogen as a fuel and an energy vector, generated through the use of primary energy and regulating the leverage of its utilization within the energy matrix." Thus, it does not refer to renewable hydrogen [3]. Nevertheless, an update is being promoted to accommodate the regulation to renewable hydrogen production [38]. Moreover, a draft renewable energy bill submitted in 2021 aims to boost the research, development, and production of renewable hydrogen as an energy alternative, as well as promoting the design of a national hydrogen plan that sets concrete goals [39].

Meanwhile, early-stage regulations are being developed in Chile and Colombia. On the one hand, Chile's enabling regulation is related to the Energy Efficiency Act (Law 21,305), which amends Art. 3 of Decree Law 2,224 of 1978 and includes hydrogen among the energies within the purview of the Ministry of Energy [40]. However, the regulatory framework must still be adapted or created to comply with the National Strategy. The country is currently developing a general regulation for hydrogen facilities for production, conditioning, storage, and consumption systems, with safety regulations mainly based on NFPA 2 [41]. For now, a support guide for hydrogen project authorization applications has been published to promote project start-up [42], while environmental assessment criteria have also been published [43, 44]. Regulations for refueling stations and modification of existing gas fitters' regulations will be under development [45].

For its part, Colombia has begun developing regulatory initiatives to recognize the importance of renewable hydrogen to decarbonizing industry. For example, the Energy Transition Act, Law 2,099, recognizes "green" and "blue" hydrogen as "nonconventional renewable energy sources" and "nonconventional energy sources", respectively. The law also enables the fiscal benefits of Law 1,715 to both hydrogen types for 30 years; these include: deduction of up to 50% of income tax, exclusion of goods and services from VAT, exemption from tariffs, and accelerated depreciation [22, 28]. In addition, Decree 1,476 promotes innovation, research, production, storage, distribution, and use of hydrogen [28]. Recently, the CONPES 4,118 document establishes actions to develop the required infrastructure for the export of hydrogen and its derivatives and its use in the maritime sector [46].

Costa Rica stands out for having national standards that allow the implementation and operation of hydrogen applications [28, 47]. Moreover, Congress is discussing a tax incentive bill for renewable hydrogen [48]. Peru does not have a legal framework in place [9], but the Peruvian Hydrogen Alliance has submitted a regulatory proposal that is under evaluation [49, 50]. In addition, renewable hydrogen was introduced within the decree of climate emergency in 2022, highlighting actions such as designing promotion programs for the technological development, use, and production of renewable hydrogen, as well as promoting the entry of electric vehicles fueled with renewable hydrogen [51].

In the case of Mexico, several regulatory frameworks and energy policies mention hydrogen, but only in terms of production and exploration. In 2021, an update to the Industrial Electricity Act recognized hydrogen as clean energy suitable for combustion or fuel cells [52]. Lastly, while Uruguay does not currently have an initiative to regulate hydrogen [53], progress related to the implementation of sector-specific regulations for safety and technical standards and permitting processes is expected in 2024 [7].

3.3. Hydrogen projects

There are over 140 hydrogen projects in different stages of development (Fig. 6), mainly in the pre-feasibility and feasibility stages (see Appendix: LAC renewable hydrogen projects for more details). Though current hydrogen production is mainly obtained from unabated fossil fuels, some countries have gained experience with water electrolysis. According to the International Energy Agency, Peru has operated the world's oldest electrolyzer for hydrogen production using grid electricity, a large-scale 25 MW alkaline electrolyzer, for ammonium nitrate production since 1965 [2]. Though it was mainly supplied with grid electricity, in 2022 it signed a PPA for renewable energy certified under the International Rec Standard [54].

In turn, the first Latin American renewable hydrogen pilot project was launched by Hychico in 2008 in Argentina.

It produces 52 t RH2/year from wind power using two alkaline electrolyzers with a collective capacity of 9.55 MW [2, 38, 55]. Additionally, small-scale electrolyzers have been operated in the region, such as Chile's Cerro Pabellón microgrid project [2, 56], Costa Rica's Ad Astra Servicios Energéticos y Ambientales (Ad Astra) pilot [2, 47, 48], and Colombia's first pilot project operated by Ecopetrol [57-59].

Figure 6: Hydrogen projects in Latin American and Caribbean countries. Based on public information; see Appendix: LAC renewable hydrogen projects for more details.

Chile has the largest number of announced hydrogen projects. In October 2021, the Ministry of Energy mentioned that there were over 60 renewable hydrogen projects in different states of development [60], but so far, 50 have been publicly announced. Of these, 25% would enter operation before 2030 [61-63]. Most of them are private, and few have a certain amount of state support. For example, in 2021, the Chilean Economic Development Agency, CORFO, launched 50 MUSD in financing for six projects [64]. In addition to this initiative, the Government presented a 1 BUSD funding ("facility") program to catalyze private investment in production and demand projects, mitigate risks, and reduce costs. This fund includes loans and contributions from the Inter-American Development Bank (400 MUSD), the World Bank (150 MUSD), the German Development Bank (100 MUSD), and the European Investment Bank (109.67 MUSD). Moreover, the European Union contributes 16.45 MUSD through the investment fund for Latin America and 830,000 USD for technical assistance. Lastly, CORFO complements it with 250 MUSD. The facility will be managed by CORFO and begin operation in the second half of 2024, aiming to leverage an investment of 12.5 BUSD [65].

Brazil has the second-largest number of hydrogen projects of the Latin American and Caribbean countries reviewed: 42 projects were identified, most of them under development. Colombia comes next with 27 projects, followed by Argentina with 11, Mexico with 9, Costa Rica with 7, Uruguay with 6, and Peru with 5.

As for operational hydrogen projects, Chile has five. For example, Cerro Pabellón is an Enel Green Power microgrid project that produces 10 t RH2/year using a 50 kW PEM electrolyzer to cover the needs of a community of technicians working at a geothermal plant [2, 56]. Other examples are (2) Haru Oni, HIF's operating pilot project using 1.25 MW electrolysis power [2, 45, 66, 67], (3) CICITEM's mobile hydrogen plant, which uses a 0.02 MW electrolysis power to test the production efficiency in different conditions [68], (4) H2GN Project for blending purpose [45, 69, 70], and (5) Anglo American's pilot project that produces 2 kg of renewable hydrogen per day and fuels forklifts, using Chile's first hydrogen station [71]. Colombia has five operational renewable hydrogen pilot projects; one aims to replace gray with renewable hydrogen in Ecopetrol's Cartagena refinery, using a 50 kW PEM electrolyzer to produce 20 kg of hydrogen per day [57-59]. The Promigas pilot project produces 1.5 t RH2/year using a 53.2 kW PEM electrolyzer for injection into the natural gas grid [28, 72]. In addition, in March 2023 the country successfully introduced Latin America's first public renewable hydrogen bus [73]. In addition, Opex introduced the first fuel cell light vehicle, Hyundai Nexo, in Medellín in July 2022 [74], while in March 2023, Ecopetrol introduced the Toyota Mirai in Cartagena's innovation center [75]. Colombia also has two 60 MW projects in the refineries that Ecopetrol, Total Eren, and EDF are developing. Costa Rica stands out with its operating transport projects, such as Ad Astra's pilot project, which has been in operation since 2013. It currently produces 2.5 kg of renewable hydrogen daily (0.8 t RH2/year) using a 5 kW PEM electrolyzer to power fuel cell vehicles (one fuel cell bus and four fuel cell light-duty vehicles) through a dispensing station [2, 47, 48, 76]. Even though Peru had the first large-scale electrolyzer in the region, no other projects are in operation [28]. Similarly, Mexico and Uruguay do not have any operational renewable hydrogen projects [28].

3.4. Renewable hydrogen potential

Each country's potential is also relevant to determine competitiveness and regional leaders that could support less developed ones. Overall, the countries reviewed have high-quality wind and solar resources for competitive renewable electricity production [2]. Brazil, Chile, Colombia, Peru, and Mexico are already committed to reaching a higher share of electricity generation from these renewable sources [20, 77-85] and therefore have a high hydrogen production potential based on renewables. Chile could produce 160 Mt RH2/year [20], while Peru, based on its experience, could achieve an electrolysis capacity of 12 GW by 2050 [86]. Meanwhile, according to Hinicio, Costa Rica would have a production potential of almost 6 Mt RH2/year in 2050 [87, 88]. Since Colombia is a significant carbon producer and one of the leading global exporters, it refers to its potential to produce blue hydrogen, expressing an interest in boosting CCUS [22, 89, 90]. For example, Ecopetrol's Strategic Hydrogen Plan sets a production target of 1 Mt of low-carbon hydrogen by 2040 [91]. Colombia's renewable hydrogen potential is over 9 Mt RH2/year when combining both hydrogen produced with electrolyzers and hydrogen produced using residual biomass [92]. Similarly, Uruguay's roadmap announces a production potential of 1 Mt RH2/year by 2040 [7]. Brazil's production potential is concentrated in the Ceará and Port of Açu hubs [93].

Besides existing hydrogen uses, potential new applications can be explored as the region has a large and diversified industry [2]. Renewable hydrogen could be primarily used in existing oil refineries, though the transport sector has gained much attention. Even though Colombia detailed that 94% of total 2030 demand of 120 kt would be related to industry, this distribution shifts and ten years later 49% of the total of 790 kt would be related to industry and 47% to transport. The transport sector would surpass industry's demand by 2050, requiring 64% of the total demand of 1.85 Mt [22]. Consistent with Costa Rica's energy supply, the country would address emissions of the transport sector to free itself of oil bills [2, 87]. Uruguay also aspires to deploying hydrogen-powered trucks, demanding 0.2 Mt RH2/year by 2040. In addition, the production of jet and maritime fuels is being considered [7].

Ammonia production has been preferred in Chile [20, 91] and the same is also expected in Argentina [2]. Meanwhile, Chile and Peru have large mining industries and applications in mining haul trucks and heavy-duty on-road trucks are being considered [2, 20, 86, 91], with a binational renewable hydrogen mining roadmap published in 2023 [95]. As for Mexico, mining trucks and ore reduction could account for nearly 80% of projected demand by 2050 [96], though hydrogen and ammonia use in large commercial vessels such as tankers, containers, and bulk carriers could be explored [84]. In addition to heavy vehicles, ammonia and fertilizer production, and blending, Brazil is also evaluating other trade-related applications for energy-intensive commodities, such as the direct reduction of iron ore or domestic low-carbon steel production [2, 97, 98].

However, hydrogen production potential not only relies on the availability of renewables and reduced costs, but also depends on the cost of electrolyzers and transport. Hydrogen can be transported over long distances via pipelines and shipping. Unfortunately, it is still expensive due to high investment costs. Some existing natural gas pipelines could be repurposed with technical modifications. For example, it has been reported that Argentina, Brazil, Chile, Colombia, and Mexico possess developed natural gas infrastructure that could be used for hydrogen transport [2].
The region is also starting to consider the port infrastructure required for hydrogen exportation. Argentina has an advantage as it already has one of the world's 37 ammonia ports [99]. Chile also expects to export renewable hydrogen and ammonia by 2025. The estimated Chilean export market is expected to reach 2.5 BUSD per year in 2030 and increase to 24 BUSD per year by 2050 [20], and the country is interested in exporting to North America, East Asia, and Europe through large-scale consortia [20, 94]. Colombia is also a potential exporter in the long term, comparable in income to its current coal exports (over 5 BUSD) [22]. The country also aims to export 3.2 Mt RH2/year by 2050, taking advantage of its privileged geographic location near some of the busiest ammonia trading routes [100]. It already has two ports for trading ammonia, which are placed in the cities of Barranquilla and Cartagena [101]. In turn, Uruguay could have an export opportunity of 1.3 BUSD by 2040 [7]. Mexico might be a competitive exporter to Asian and European destinations due to its potentially low hydrogen production cost and privileged geographical position [2, 27]. Brazil also has an advantage as major European ports administer the ports of Açu and Pecém. Such involvement in logistics opens opportunities for international trade flows and investments from Europe to renewable hydrogen in Brazil [102].

Investment in the development of the renewable hydrogen industry would also promote job creation and capacity building, relevant aspects for the region. Some countries have considered this in their strategies, while others have projections based on studies. Chile has recognized that the industry's development could create almost 100,000 jobs by 2050 [20, 103]. Additionally, national entities have been tasked with developing and studying new occupational profiles that would be required [104]. Argentina expects 50,000 jobs to be available in the renewable hydrogen value chain by 2050 [23]. Uruguay estimates 6,000 new jobs in 2030 and over 35,000 direct skilled jobs in plant construction, operation, maintenance, logistics, and technical education in 2040 [7]. Colombia also highlights the creation of 7,000 to 15,000 direct and indirect jobs in 2020-2030 [22]. For its part, renewable hydrogen strategy of the Government of Rio Grande do Sul in Brazil plans to create more than 40,000 new jobs [105].

Competitiveness measured as the levelized cost of hydrogen (LCOH) could range from 1.2 USD per kg of renewable hydrogen to 4.8 USD per kg of renewable hydrogen (Table 3). Brazil, Chile, and Uruguay would have the potential to achieve the lowest costs, close to 1.5 USD per kg of renewable hydrogen by 2030. The LCOH is in the region is expected to fall sharply by 2050, to between 0.8 and 1.9 USD per kg of renewable hydrogen. Thus, competition for leadership will be intense and dependent on developing low-carbon hydrogen production, implementing regulatory regimes, and recognizing international certification in each country [1].

An approach to measure and evaluate the hydrogen industry's progress in Latin America and the Caribbean is the regional hydrogen economy index proposed by Hinicio and Newenergy. This index assesses the different variables that impact its development – such as public policies, regulations, incentives, or projects – by collecting responses to a survey sent to stakeholders in each country and validating with data. In 2022, the aggregate results positioned Chile, Colombia, Brazil, and Uruguay with the highest index due to governments' willingness to support the industry and the private sector's interest in developing projects (Figure 7) [110, 111]. Meanwhile, preliminary results of the H2LAC Index 2023 have been presented, showing that hydrogen projects reached a total of 150, up 74% compared to the previous index, of which almost two-thirds were in Brazil and Chile. Chile, Colombia, and Brazil maintained their leadership positions [112].

Table 3: Comparison of the levelized cost of renewable hydrogen among Latin American and Caribbean countries, measured in USD/kg, [2, 7, 20, 22, 24, 96, 99, 104-109]

LCOH\Country	Argentina	Brazil	Chile	Colombia	Costa Rica	Mexico	Peru	Uruguay
2030	1.5 – 1.6	1.3 – 1.5	1.3 – 1.8	1.7 – 3.7	2.0 – 4.8	2.55 – 3.25	2.6	1.2 – 1.9
2050	N/A	N/A	0.8 – 1.1	1.5 – 2.4	1.2 – 1.9	1.22 – 1.50	1.0 – 1.3	1.0 – 1.4

Figure 7: H2 LAC Index 2022: Aggregated results [110, 111].

4.Country briefs

As previously discussed, Latin American and Caribbean countries have made different degrees of progress with the renewable hydrogen economy. Considering the eight countries of interest the following section summarizes for each country the industry's current context and policies, hydrogen projects, and the nation's potential.

Argentina

Current context	Renewable energy availability, installations, and regulation	• The country has high-quality wind and solar resources and therefore competitive renewable electricity [2]. The Northeast region has high solar radiation levels, with 2800 kW/h per square meter yearly [23]. • In 2021, 59.1% of electricity was generated from conventional thermal power (natural gas, coal), 25.2% from hydroelectric power, 11.6% from renewables (65.8% of which is wind power), and 4% from nuclear power. Of the total installed capacity incorporated in 2021, 97% corresponded to renewable energy sources through 26 large-scale projects in 10 provinces. As of 2022, the installed power capacity was 42,927 MW. Regarding energy demand, residential demand represents 42.6%, the commercial market 25.7%, and large-scale industrial and commercial demand 25.6% [9]. • Law 27,191 (enacted in 2015) sets a goal of 20% RE in the national consumption by 2025, amending the preceding law of 2006. Draft bills are being developed, such as one promoting the creation of a National Green Hydrogen Development Fund (FONHIDROV) and another declaring the decarbonization of the energy matrix as a matter of national interest and detailing the preparation, monitoring, and updating of the National Strategic Plan for Renewable Energies (presented in 2021) [38, 39].
	Emissions and emissions reduction commitments	• 53% of emissions are related to energy production, 37% to agriculture, livestock, and other land uses, and 6% to industrial processes and product uses. • In 2021 Argentina publicly pledged to achieve carbon neutrality by 2050 [2, 23]. It committed to limiting GHG emissions to 313 Mt CO2 by 2030 under the 2020 NDC [99].
	Transport sector	• Road freight transport accounts for over 90% of total domestic freight transport. CNG accounts for 12% of total road transport energy demand [113]. • Due to pilot projects and discussions of CNG corridors to support its use along main routes, CNG and LNG will be used as fuel for heavy-duty transport. Electric and hybrid vehicles account for less than 10,000 units [113].
	Carbon pricing	• In 2018, the Government implemented a carbon tax for most liquid fuels, replacing previous fuel taxes. The carbon tax is also levied on some solid products (mineral coal and petroleum coke). The price for most liquid fuels is USD 5/ton CO2eq [114].
	Current H2 production	• H2 production is mainly from unabated fossil fuels [2]. The state oil company YPF produces gray and blue H2 (36% of the total national production), consumed in situ for hydrocarbon processes [99]. • Around 400,000 tons of gray H2/year are produced [99].
	Current H2 use	• Oil refining, chemicals-NH3 and methanol, iron, and steel-DRI, iron and steel-Blast furnace, cement [2]. • H2 demand was 395 kt in 2020; 2/3 pure H2, 1/3 mixed H2. Argentina is the only country in the region with considerable H2 demand for the four main current H2 applications in industry: ammonia production (33%), oil refining (27%), methanol (15%), and DRI (16%) [2, 99]. 33% of the H2 goes to producing fertilizers based on ammoniacal urea. At the same time, some is exported as ammonia from the port of Bahia Blanca, where its largest plant is located [2, 99].
H2 policy	H2 policy plan, roadmap, or strategy	• Yes: 2030 National Low-emission Hydrogen Strategy (launched, 2021) [23, 115]. • In 2014, a National Hydrogen Plan was presented with a 16-year roadmap [38, 116]. However, this plan has not been implemented due to the change of Government [33]. • The 2030 National Low-Emission Hydrogen Strategy was launched in 2021 and aims to create a roadmap to promote public-private collaboration, investment in science and technology, and industrial participation [23, 115].
	Regulatory framework	• The regulatory framework includes the Hydrogen Promotion Act (2006); H2 production, energy use, and R&D are of national interest, and its updating is being promoted in Congress to accommodate the regulation on RH2 production [2, 38, 39]. • Argentina also has H2 safety standards through participation in the ISO TC 197-ISO-IRAM 15916 [2]. • A new draft RE bill (submitted in 2021) aims to boost research, development, and production of RH2 as an energy alternative; it seeks to drive the design of a national H2 plan that sets concrete goals to be met by the end of this decade [39]. • Argentina’s draft hydrogen bill was submitted to the lower house in 2023 and has been passing through the legislature since then and is expected to subject to public debate. Reports say that the bill considers at least 35% of renewable hydrogen project equipment being sourced in Argentina, rising to 45% within five years of the bill’s passing and 50% in ten years. It also envisages significant tax breaks for hydrogen developers, provided they meet local content requirements [117, 118].
	Other announcements	• A Green Hydrogen Strategic Plan was developed for the Province of Río Negro, identifying the capacities and the available resources and concludes its H2 export potential using its port [23].

Argentina

Projects and initiatives	Total number	• 11 RH2 projects.
	R&D	• The scientific and technological development of H2 is one of the pillars of the country's 2030 national H2 strategy [2]. • Over one-third of participating groups of the H2TRANSEL Ibero-American research network are based in Argentina [2].
	Financing and investment	• The national Fund for the Promotion of Hydrogen is in the renewal process to include RH2 [28]. • Productive investments are committed to over 10 BUSD [115]. • It has been announced that Argentina will partially benefit from the EU's 10 billion EUR fund, which is destined for several bilateral agreements. However, it is not known how much funding will receive Argentina [119].
	Collaboration	• National alliance: H2AR consortium [2]. • International collaboration: Argentina is part of IRENA [23]. Moreover, within the context of the strategic partnership built between Argentina and Japan, both countries signed a Memorandum of Cooperation to boost the development of H2 as a pollution-free energy source [120]. • In 2023, a MoU between the EU and Argentina establishes collaboration to develop and promote renewable energy and energy efficiency, as well as the use of hydrogen and its derivatives, while another MoU manages the value chains of critical raw materials for the energy transition [121, 122].
H2 potential	H2 production	• Blue H2 will gain protagonism in 2036-2041, as Argentina has significant NG production due to having the second-largest NG reservoir in the world [23]. There are also abundant biomass resources in the central and northeast regions. Moreover, H2 based on nuclear power is under discussion, considering Argentina's experience [23]. • The nation will restore the duty-free zone to boost RH2production, which is among the actions to transform the province of Sierra Grande into a development pole. • The country is pursuing the goal of 5 GW+ of electrolysis capacity by 2030 [115]. Thus, Argentina could produce 1,000 Mt/year of RH2 by 2030 [115].
	H2 application and demand	• Argentina has a large and diversified industrial sector. The country's potential is in exploring options for low-carbon H2 in existing and new end uses, leveraging existing industrial capabilities and value chains and decarbonizing existing production. Low-carbon H2 blending in CNG could reach 20% using existing LDVs. Moreover, the H2 demand is sizeable for all four main industrial H2 applications: oil refining, production of NH3, methanol, and DRI [2].
	Infrastructure, transport, and storage	• The NG infrastructure is developed. Transmission pipelines between the far south and far north are underutilized and could be attractive for repurposing in the long term [2]. The pipeline is 16,000 km long [23]. • The country has one of the 37 NH3 ports in the world, which is strategic as NH3 has the advantage of having a mature transportation infrastructure and solid safety parameters and standards [99]. • Hychico has an underground storage facility [2].
	H2 export and trade	• Low-carbon H2 export could be of significant volume [2]. By 2050, 15 BUSD could be exported due to RH2 [23]. • NH3 would be shipped from the port of Bahía Blanca [2].
	CCUS potential	• CCUS potential is low-medium. A CCUS Atlas is in preparation [2]. • Industrial clusters are at the Port of Bahía Blanca and Port of Campana-Zárate [2].
	Human capital	• 50,000 jobs could be created by 2050 due to the RH2 value chain [23]. • Also, the Australian company Fortescue announced that it would invest 8.4 BUSD in Argentina to produce RH2 in the province of Río Negro, which will create more than 50,000 jobs, both direct and indirect, and in the first stage will only be oriented for export [123].
	LCOH (2020)	• 1.4-1.8 USD/kg gray H2 [99]
	LCOH (2030)	• 1.5-1.6 USD/kg RH2 [99]

Brazil

Current context	Renewable energy availability, installations, and regulation	• Brazil has high-quality wind and solar resources and therefore competitive renewable electricity [2]. • According to the National Energy Balance (BEN), Brazil reached 134.8 Mtoe of RE in 2021, representing 44.7% of total domestic energy supply. Regarding the distribution of RE sources, energy from sugarcane biomass represented 16.4%, hydropower 11%, firewood and charcoal 8.7%, and other renewable sources contributed the remaining 8.7%, including wind and solar. Regarding electricity generation, in 2021, REs represented 78.1% of the energy matrix. Hydroelectric power accounts for 53.4% of the country's electricity generation. Due to the scarcity of rainfall that affected hydroelectric generation, the share of natural gas-fired thermoelectric plants increased to 12.8% in 2021. Nevertheless, there was significant growth of wind and solar energy participation in the matrix, reaching 72 TWh (10.6%) and 16.8 TWh (2.5%) in 2021, respectively [11, 124, 125]. • Electricity consumption accounted for approximately 63% of the country's energy consumption in 2020: industry (32.1%), transport (31.2%), the energy sector (11.2%), households (10.8%), agriculture and livestock (5.1%), services (4.7%) [11, 124, 125]. • The country has existing structures for further expansion of renewables thanks to the private sector's experience and proven bidding and contracting models that allow short-term contracting of additional RE generation capacity at favorable production costs [11, 124, 125]. Brazil's RE targets are embedded in its Ten-Year Energy Expansion Plan (PDEE), which aims for RE to account for 42.5% of the total primary energy supply by 2023. The 2007 Brazil National Climate Change Plan (Decree 6,233 of 2007) set the goals of increasing electricity co-generation, mainly from sugarcane bagasse, to 11.4% of total supply in 2030, and adding 34.5 GW of hydropower capacity as scheduled in the PDEE [78]. According to estimates of the National Energy Plan, PNE 2050, in the Expansion Challenge scenario, wind energy could reach an installed capacity of 110-195 GW by 2050, with 50-85 GWh of energy generation, while solar photovoltaic energy is expected to expand through 2050, reaching an installed capacity of 27-90 GW and 8-26 GWh of centralized power generation [126, 127].
	Emissions and emissions reduction commitments	• Land-use changes accounted for 44% of total GHG emissions in 2021, while agriculture and the energy sector accounted for 28% and 19%, respectively [11]. The largest driver of overall energy related GHG emissions is CO2 emissions from fuel combustion, which totaled 414 Mt CO2eq in 2021. The transport sector contributes 47% of emissions, followed by the industrial (27%) and power sectors (9%) [128, 129]. • Brazil pledged to reduce its GHG emissions by 37% in 2025 and 50% by 2030, according to the 2015 NDC, based on emissions recorded in 2005 [125], while a 2050 carbon neutrality goal was announced in 2020 [2].
	Transport sector	• Road freight transport accounts for over 50% of total domestic freight transport. An FCEV bus prototype is being developed with funds from the utility-funded R&D investment obligations program of the power sector regulator, ANEEL [2].
	Carbon pricing	• In total, 5.9% of GHG emissions in Brazil are subject to a positive Net ECR in 2021. Brazil does not levy an explicit carbon price. Fuel excise taxes, an implicit form of carbon pricing, covered 5.9% of emissions in 2021, while fossil fuel subsidies covered 1.6% in 2021. In 2021, fuel excise taxes amounted to EUR 0.41 on average [130]. • Brazil is currently considering the implementation of an ETS (2021) [2].
	Current H2 production	• H2 is mainly produced from unabated fossil fuels [2]. The country had 48 kW of electrolysis capacity as of June 2021.
	Current H2 use	• Oil refining, chemicals-NH3 and NH3-based fertilizer production, iron and steel-Blast furnace, cement [1, 98]. • In 2019, the H2 demand was 465 kt H2, mainly gray H2. 320 kt H2/year is for hydrotreatment and hydrocracking of hydrocarbons in refineries and 145 kt H2 /year is for ammonia-based fertilizer production [98].
H2 policy	H2 policy plan, roadmap, or strategy	• No: National H2 strategy under development [28]. Technical note for strategy (published) [29]. • In 2005, the Ministry of Mining and Energy (MME) launched a Roadmap for Structuring the Hydrogen Economy in Brazil, focusing on priority milestones for H2 production [131]. • The Energy Research Corporation (EPE) released an initial technical document: The basis for a national H2 strategy [2]. • In 2021, the Brazilian Government launched the Guidelines for the National H2 Program (PNH2); related actions are under development [2, 98, 125]. The PNH2 covers six priorities: (1) Reinforcing R&D&i and technological foundations, (2) Capacity-building and human capital formation, (3) Energy planning, (4) Legal and regulatory framework, (5) Market development and competitiveness, and (6) International Partnerships and cooperation [125].
	Regulatory framework	• Brazil has safety standards for H2 as it participated in the ISO TC 197-ABNT IEC/TS 62282-1:2018.
	Other announcements	• The National Energy Plan 2050, published in December 2020, describes H2 as a disruptive technology and strategic element in decarbonizing the energy matrix and for energy storage [124]. • The government of Rio Grande do Sul published its state RH2 strategy [105].

Brazil

Projects and initiatives	Total number	• 42 RH2 projects.
	R&D	• CNPE established H2 as one of the priorities for energy R&D spending [2]. Moreover, CNPE Resolution # 2/2021 sets increasing the share allocated in H2 projects as a priority area for R&D&i, which is 1% of total Energy R&D&i from 1999 to 2018 [125, 131]. • The Fuel Cell System program (2002) focused on developing domestic fuel cell technologies [2]. • MME, GIZ, and SENAI signed a cooperation agreement to create the first Center of Excellence in Green Hydrogen in Nata, considering five regional RH2 education and training hubs in Brazil [98].
	Financing and investment	• IDB supports feasibility studies and road-mapping processes [2]. • The Brazilian National Development Bank offers special financing conditions for renewables and low-carbon technologies, including low-carbon H2 [125]. • The Government invested around 100 MUSD for the next five years [93]. • The EU promised investments of 2 billion EUR (2.16 BUSD) for Brazil's renewable hydrogen production capability and energy efficiency [132].
	Collaboration	• National alliance: Brazilian Hydrogen Association • International cooperation: Brazil has been engaged in international cooperation on low carbon H2 under the German-Brazilian Energy Partnership, "H2 Brazil" in the "German – Brazilian Power-to-X Partnership Program," the "US-Brazil Energy Forum for World Commerce and Development," the "UK Brazil Energy Program," "India and Brazil on Bio-energy Cooperation," "BRICS – Energy Research Cooperation Platform," and the "Brazilian Energy Compact on Hydrogen established at UN High-Level Dialogue on Energy," among others [125].
H2 potential	H2 production	• Brazil's focus areas involve NG and ethanol reforming, water electrolysis using RE, and waste biomass. • The Ceará Green Hydrogen Hub (operational by 2025) will have an electrolysis capacity of 5 GW and RH2 production of 900,000 tons/year, while Green Hydrogen Hub Porto do Acu (in operation by 2026) will have a RH2 plant with 300 MW electrolysis capacity to produce 250,000 tons/year of renewable NH3 [93, 97].
	H2 application and demand	• Brazil has a large and diversified industrial sector. The country's potential is to explore options for low-carbon H2 in existing and new end uses, leveraging existing industrial capabilities and value chains and decarbonizing existing production [2]. • Focus areas are heavy vehicles, NH3/fertilizer production, and blending with NG [93, 97]. In addition, other trade-related applications for energy-intensive commodities are of interest, such as the direct reduction of iron ore to produce sponge iron in HBI for export or domestic low-carbon steel production. Moreover, a potential application is using H2 in combination with renewable CO2 to produce green naphtha via the Fischer-Tropsch reaction as a synthetic substitute in the production of petrochemicals and fuels [98, 125].
	Infrastructure, transport, and storage	• NH3 and urea production were below installed capacity In 2019 due to competition from external producers and high gas prices [2]. • Brazil has three major fertilizer plants in the states of Sao Paulo, Bahia, and Sergipe, which were idle in 2019. The 4th plant is an NH3-based fertilizer production site in Paraná that was the only ammonia-based fertilizer production site in operation during 2019. The underutilization of these infrastructures led to higher fertilizer imports. Finally, the Sergipe plant resumed in 2021 [2]. • The country also has a developed NG infrastructure [2]. • The ports of Pecém and Rotterdam signed a cooperation agreement to promote public-private initiatives between the Netherlands and Brazil. An investment of 8 BUSD is expected in renewable hydrogen projects and 443.5 MUSD in port infrastructures [133].
	H2 export and trade	• Low-carbon H2 could be exported in significant volumes [2]. • The ports of Açu and Pecém are administered by major European ports (Rotterdam-Netherlands; Antwerp-Belgium). Such involvement of major European logistics players opens opportunities for international trade flows and investments from Europe to RH2 in Brazil [102].
	CCUS potential	• CCUS potential is high as Brazil has the only operational commercial CCUS facility in LATAM: Petrobras Santos Basin Pre-Salt Oil Field CCS project [2]. • Moreover, Brazil has the world's only offshore EOR project in operation. Since 2013, CO2 has been separated from gas extracted with oil from two ultra-deepwater fields. Around 3 Mt CO2/year are reinjected in a nearby pre-salt reservoir for EOR. Though it reduced energy sector emissions, it did not capture emissions linked to the combustion of fossil fuels [2]. • Industrial clusters are in Rio de Janeiro, Pernambuco, and Ceará [2].
	Human capital	• The Green Hydrogen Strategy of the Government of Rio Grande do Sul plans to create more than 40,000 new jobs [105].
	LCOH (2030)	• 1.3 USD/kg RH2 [109]-1.5 USD/kg RH2 [108]
	LCOH (2040)	• 1.25 USD/kg RH2 [108]

Chile

Current context	Renewable energy availability, installations, and regulation	• The country has high-quality wind and solar resources and therefore competitive renewable electricity [2]. Its potential is 1,800 GW in all NCREs (70 times Chile's demand), broken down as follows: 509+ GW concentrated solar; 1,180+ GW photovoltaic, 191+ GW onshore wind, and 6 GW run-of-river hydropower [20]. • 80% of electricity will come from RE by 2030 [45, 98]. • For example, the annual solar yield in the Atacama Desert is 2,500 kWh/m2 (GHI) [134, 135]. • Regarding wind resources, winds in the far south blow with the same energy on land as offshore. Wind turbines 120 meters high can reach plant factors of over 60% on land, equivalent to offshore turbines in other countries [20]. The average wind speed in Chile ranges between 4.1 and 10.2 m/s, depending on the region. In the Aysén Region the maximum wind speed is 22.9 m/s, while in the Magallanes Region, the minimum and maximum wind speeds are 4.0 and 21.3 m/s, respectively [136]. • Moreover, Chile has significant energy curtailment, accounting for 1,471.02 GWh in 2022 (considering both wind and solar). This energy could be exploited to produce RH2 on-site [137]. • Chile met the interim goal of generating 20% NCRE (excluding large hydro) by 2025 ahead of schedule [134]. Solar and wind energy surpassed coal in electricity generation for the first time in 2022. Of the 62,429 GWh of annual generation, 20,014 GWh, or 29%, were produced by NCREs, while 27% was produced by coal [138]. Electricity generation in the SEN was 6,483 GWh in February 2023, of which 42.2% was thermoelectric, 19.4% conventional hydroelectric, and 38.3% NCREs [139]. Regarding NCRE projects, there are 14,204 MW in operation, broken down as follows: 596 MW biomass, 4,582 MW wind, 84 MW geothermal, 654 MW mini hydro, 8,118 MW solar-PV, 108 MW solar-CSP, and 60 MW biogas. Moreover, there are 6,059 MW in projects under construction, divided into 1,429 MW wind, 47 MW mini-hydro, and 4,580 MW solar PV [139]. • Several regulations for the RE market exist [140]. GIZ's Regulatory Map of the Chilean Energy Sector summarizes the most relevant ones [141]. In 2022, Chile enacted the Storage and Electromobility Act, which among other things promotes the participation of storage systems, avoiding the waste of the RE generated [80]. Chile will increase the share of RE in the electricity mix by promoting investment in energy storage to alleviate transmission congestion and accelerate the closure of coal-fired plants [81].
	Emissions and emissions reduction commitments	• The country's GHG emissions (excluding LULUCF) totaled 112,3 Mt CO2eq in 2018, a 128% increase over 1990 and 2% since 2016. The main GHG emitted was CO2 (78%), followed by CH4 (13%), N2O (6%), and fluorinated gases (3%). The energy sector produced 77.4% of CO2eq emissions: 38.8% from the electricity sector, 32.9% from transport, 18% from industry (of which around 7% were from mining [142]), 7% from construction, and 1% from fugitive emissions [12]. • Coal-fueled power generation currently accounts for around 40% of the electricity mix [134]. Furthermore, the mining industry uses CAEX trucks that consume 3,500 L diesel/day. As there are more than 1,500 mining trucks operating daily in Chile, over 5 Mt of CO2 emissions per year could be displaced by replacing diesel with renewable hydrogen [143]. Moreover, 2 Mt CO2/year was emitted from H2 production in 2019 due to the primary end uses (chemicals and oil refining) [2]. • In 2020, Chile decided in its NDC to become carbon neutral by 2050, which was officially ratified in 2022 with the Climate Change Framework Act. Two key regulations for implementing it were approved: the first regulation establishes procedures associated with climate change management instruments, while the second regulation implements the law's governance model [144, 145]. • According to the Ministry of Energy, 24% of the emissions reduction required to achieve carbon neutrality by 2050 will be thanks to H2 [12]. • Moreover, the 2019 Coal Retirement Plan pledged to close all coal-fired power plants by 2040. This original schedule has been constantly modified and accelerated, and in 2021 the commitment was made to close 50% of coal-fired power plants by 2025 [146]. • The mining industry also has some reduction commitments. In 2020, Codelco announced plans to reduce its emissions by 70% by 2030, focusing on electrification measures and H2 uses [2]. Large-scale copper mining companies associated with the Mining Council (Consejo Minero),, which represents 97% of national copper production) have committed to reducing GHG emissions. Some goals are specific to Chile, related to emissions reduction and carbon neutrality. By 2023, over half of the electricity supply contracted by large mining companies will be RE [147].
	Transport sector	• Transportation represents over 1/3 of energy consumption and 26% of the energy sector's emissions are transport-related [12]. Road freight transport accounts for >90% of total domestic freight transport [148]. • Targets and ambitions for deploying electromobility have been announced, with a focus on LDVs and urban buses [2]. A national Electromobility Strategy was published [148]. The government established that 100% of sales of light, medium, and public transport vehicles (buses and taxis) and major mobile machinery would be zero emissions by 2035. More than 1,700 buses in circulation will be electric. By 2040, 100% of the sales of minor mobile machinery (construction, agricultural, and forestry machinery) will be zero emissions. And by 2045, 100% of freight transport and intercity bus sales will be zero emissions. Initiatives to achieve the established goals are efficiency standards for new vehicles (in the Energy Efficiency Act), promotion programs for long-distance fleets, reconversion of combustion vehicles to electric cars, and the draft Energy Transition bill [149]. • An agreement between the Ministries of Transport, Environment, and Energy, and 25 private and academic institutions will promote a RH2 pilot bus, benefiting Santiago's RED rapid transit system [150]. Moreover, the Ministry of Transport opened an RFI on RH2 trucks for public roads [151]. Lastly, the National Green Hydrogen Strategy considers the use of H2 in mining trucks (30%), heavy load trucks (37%), and long-range buses (15%) [20].

Chile

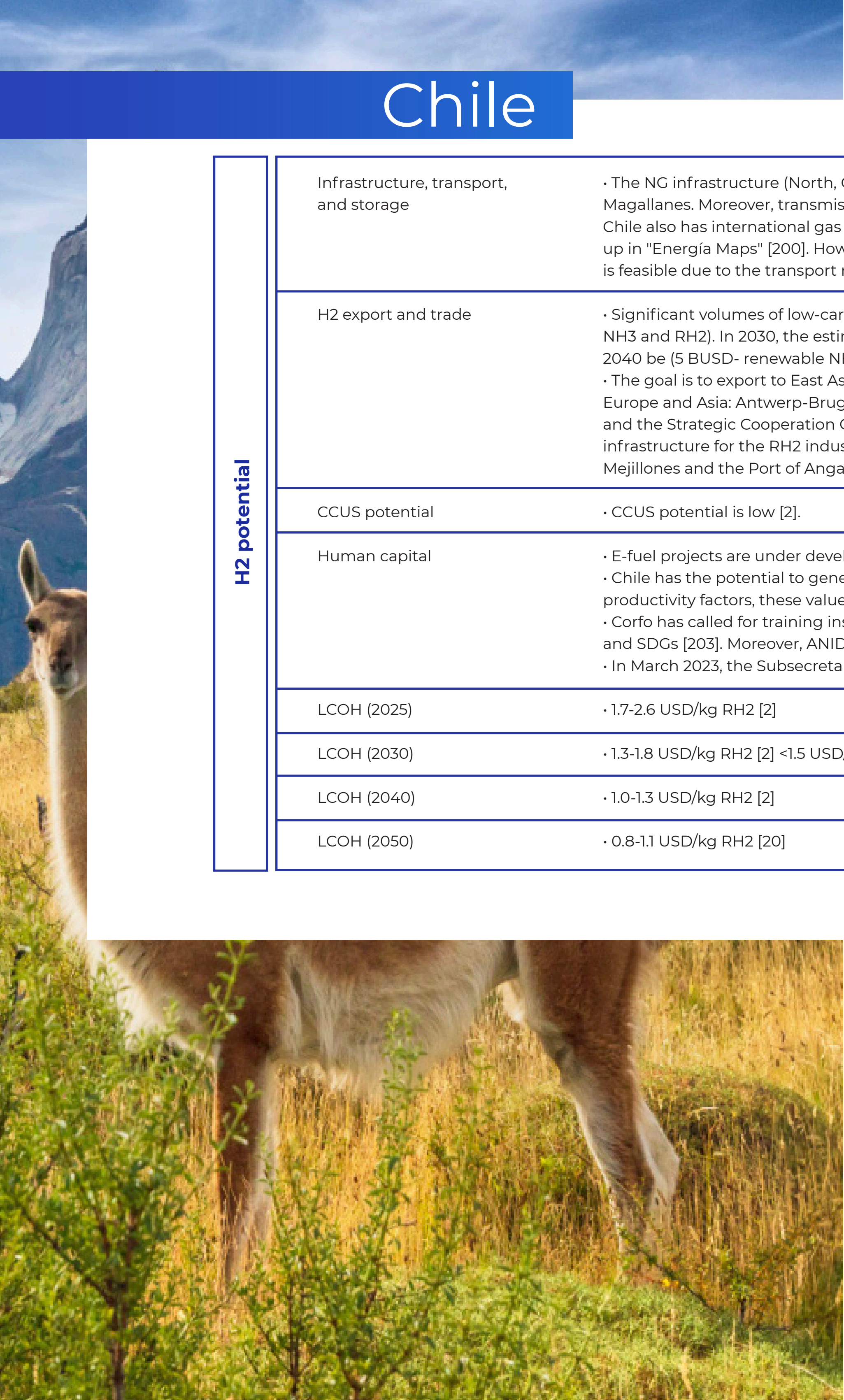
Current context	Carbon pricing	• The carbon tax applies to CO2 emissions mainly from the power and industry sectors. It applies to installations with thermal power exceeding 540 MW between furnaces and turbines. The tax reform, approved in 2020, modifies the threshold and by 2023, it will apply to installations that emit 25,000 t CO2 or more and to those releasing over 100 tons/year of PM into the air [114]. • The tax covers all fossil fuels and is 5 USD/t CO2eq (2020) [114]. • There are efforts to implement a system to limit GHG emissions [2]. According to a preliminary document for the Ministry of Energy's comprehensive "National Energy Policy", the carbon price will increase to 35 USD/ton CO2 by 2030 [45, 98].
	Current H2 production	• Chile does not currently produce RH2 to scale [134] and H2 production is mainly carried out from unabated fossil fuels, especially NG [2, 152]. A total of 70 kt of H2 was produced from NG in 2021 [153]. • The installed electrolysis capacity was 1 MW in January 2022 [45, 98]. • Many projects have been announced [63, 158].
	Current H2 use	• Oil refining, chemicals-methanol, iron and steel-blast furnace, cement [2]. The main H2 application concerns oil refining and methanol production [2, 152, 155]. • In 2020, 95% of the nation's H2 production was related to its use in the Biobío and Aconcagua refineries [155]. ENAP's Aconcagua and BioBío refineries consume 24,000 tons of H2/year and 22,000 tons of H2/year, respectively. Thus, ENAP's total consumption is 46,000 tons of H2/year, supplied by the company Linde S.A., which has H2 production plants using NG near each refinery [152]. Moreover, Chile is the second-largest methanol producer in LATAM [2, 155]. According to the IEA, over 80% of domestic demand in 2019 was for methanol production [2]. Other uses include the food industry (oil and margarine production) and glass production [156, 157].
H2 policy	H2 policy plan, roadmap, or strategy	• Yes: National H2 Strategy (published 2020) [20]. • Chile is the first LATAM country to launch a comprehensive H2 strategy [2]. The strategy identifies primary opportunities to replace fossil fuel based H2 in existing refineries and new applications in long-distance and heavy-duty transport [2, 20]. fuel • In addition, the Inter-ministerial Committee for the Development of RH2 has been created with the participation of 11 ministries. Its functions are to support the implementation of the National Green Hydrogen Strategy; to manage state initiatives for industry development; to promote capacities to develop technologies and RH2 applications, including technology and knowledge transfer, as well as to promote the training of professionals and specialized technicians, among others [158]. • The 2023-2030 Action Plan was launched in March 2023, aiming to strengthen the measures and goals of the National Strategy and including the participation of communities, civil society organizations, academia, and industry. In this context, an advisory council was convened that brings together representatives of different interest groups associated with the RH2 value chain. It also considers the formation of a strategic committee that will deliver guidelines and policies with broad consensus for the development of this industry [21]. Some of the measures envisaged are a regulatory roadmap, a reform to incorporate hydrogen as a typology in the environmental impact assessment service, public baselines, reinforcement of services that deliver critical permits, a shared logistics infrastructure development plan (ports), among others [159]. As for public baselines, the Ministry of the Environment published a call for the construction of public baselines for the provinces of Magallanes and Tierra del Fuego within the framework of the sustainable productive development program, with funding of 1billion CLP [160].
	H2 production goal (horizon)	• 200 kt/year (2025) [20].
	GW electrolysis goal (horizon)	• 5 GW of electrolysis capacity to be operated or under development by 2025 [20]. 25 GW of electrolysis capacity to be installed or under development by 2030 [20].
	Regulatory framework	• The Chilean government has taken the first steps toward creating a legal framework. As of September 2022, the entry into force of the Energy Efficiency Act, Law 21,305, allows the recognition of H2 as a fuel, enabling the Ministry of Energy to regulate safety aspects in the production, use, and transport of RH2 by other legal means such as decrees and regulations [40]. • Moreover, the Ministry of Energy is developing the general regulation of H2 installations for production, conditioning, storage, and consumption systems, mainly based on NFPA 2. The development of this regulation began in September 2020, and its public consultation process was completed in February 2022 [41]. In the future, the regulation will most likely be updated to include liquefied H2. • A guide supporting special H2 project authorization was published by the Superintendency of Electricity and Fuels (SEC). It guides those interested in implementing H2 projects when considering an installation related to the production, conditioning, transport, distribution, storage, or consumption of H2 as a fuel [42]. • Environmental criteria were also published. The "SEIA Assessment Criteria: Introduction to green hydrogen projects " (January 2022) addresses the technical standards that proponents must present in the description of RH2 production and storage projects for environmental assessment. In March 2023, the criterion on "Comprehensive description of projects for the production of green hydrogen in the SEIA" was published [43, 44]. • Moreover, in 2021, a process for the direct allocation of public lands for RH2 projects was announced and contracts are expected to be signed between May and June 2023 [161]. • In addition, in November 2022, circular DDU 470 was issued to clarify which type of urban land use corresponds to H2 projects [162]. • In the short term, Chile aims to develop the following regulations: (1) the H2 Fueling Station Regulation and (2) the modification of the existing gas fitters' regulation [45, 94]. A draft bill to promote the production and use of RH2 is under review. It aims to: (1) regulate the participation of RH2 in networks of NG concessions (blending) and (2) legally enable the National Petroleum Company (ENAP) to produce and sell RH2 and derivates [163]. In addition, a public-private agreement for RH2 use in the mining sector is being discussed, and a "Tax instrument Strategy for the energy transition" will be agreed upon and published to chart the future course on carbon and fuel taxes [45, 94].

Chile

H2 policy	Other announcements	• The Carbon Neutrality Plan announces that H2 will be responsible for a 24% reduction in energy sector emissions by 2050 [2]. • The Ministry of Energy released the Preliminary Report for the Long-Term Energy Planning Process, including the targets and impact of the RH2 Strategy goals on the electricity transmission and distribution system. This report will become an input for the Transmission Planning Process, which later defines the construction of transmission lines and electrical infrastructure [45, 94]. • The National Electromobility Strategy includes goals on RH2 and fuel cell applications such as (1) 100% electric vehicle sales in 2035 and (2) 100% of public transport sales (buses and taxis) will be zero emissions [45, 94]. • The energy agenda for 2022-2026 includes (1) promotion of the first 10 RH2 projects and the establishment of strategic local RH2 ecosystems in the Magallanes and Antofagasta Regions, (2) the development of a strategic plan to ensure sustainable use of the territory and cooperation with other ministries to deploy key shared infrastructure, (3) the creation of enabling regulations, including certification and sustainability standards, and (4) the development of complementary initiatives in coordination with organizations such as ENAP, Corfo, the Mejillones Port Complex, and Codelco [164]. • In 2021, Corfo opened an RFI on RH2 projects in Chile to execute projects larger than 10 MW before the end of 2025 [165]; this initiative led to the selection of six RH2 projects with 50 MUSD funding. The projects selected include the following companies: Enel, CAP, GNL Quintero, Engie, Air Liquide, and Linde [64]. Moreover, Corfo announced another RFI for companies interested in manufacturing electrolyzers in Chile [166]. • There has been progress charting a regional RH2 roadmap called "Corfo Regional Transformation: Green Hydrogen in Far-South Patagonia"; it aims to consolidate information regarding relevant issues for developing the industry in the Magallanes Region. It also includes deadlines, the program's vision, and the elements and gaps related to H2 [134, 167]. • "Misión Cavendish" (2020-Innovation Club, H2 Chile, with the collaboration of the Corfo Solar and Energy Innovation Committee, GIZ, the Chilean Ministry of Energy, and Ata Insights) seeks to encourage and prepare the public, private, and academic sectors with a series of activities to promote the development of RH2 projects [168]. • As for 2023, private sector announcements include a joint development agreement between ENAP, HIF, Total Eren, and HNH Energy to transform the Ladero terminal into a port to enable the necessary infrastructure for the collection, storage, and transport of equipment and machinery [169]. Moreover, Anglo American convened public and private actors to jointly develop a study to analyze the economic feasibility and benefits of deploying an RH2 hub [143, 170]. For its part, ENAP has announced the most significant investment plan in its history, which considers around 3.5 BUSD in the next five years, with investments in diversification to cleaner energies such as green and blue H2, fuel NH3, and SAF [171].
Projects and initiatives	Total number	• 50 RH2 projects.
	R&D	• Some R&D projects have been announced. CORFO is supporting at least 3 R&D projects to develop hybrid diesel/H2 mining haul trucks in partnership with the private sector and academia [2], such as the UTFSM Consortium project (with CODELCO) [2, 172]. The project “H2IN-Multidimensional study of the hydrogen value chain applications in local industry” aims to undertake a multidimensional and comprehensive assessment of the RH2 value chain in Chile while empowering public and private decision-makers by improving their understanding of the current energy transition [45, 94, 173]. Other R&D projects are the Moowi/UACH [174, 175] and HYDRA projects (2022) [2, 176]. Moreover, researchers from Fraunhofer Chile's Center for Solar Energy Technologies developed the Green Hydrogen Explorer, which provides a preliminary techno-economic assessment for RH2 production, storage, and transportation projects with the use of photovoltaic and concentrated solar power technology [177, 178] • The Ministry of Energy is collaborating with the Ministry of Science, Technology, Knowledge, and Innovation on initiatives aimed at scaling up R&D in H2-technologies, including up to 400 MCLP in funding for each solution [45, 94]. • In April 2023, the Corfo Council awarded the tender to implement the Chilean Institute of Clean Technologies (ITL) to the Association for the Development of the Technological Institute (ASDIT), a consortium led by the Alta Ley Corporation with participation by 11 Chilean universities, national and foreign technological institutes, and various public and private companies. The initiative is projected to promote regional and national development through R&D in solar energy, RH2, and sustainable mining, among others [179].
	Financing and investment	• Feasibility studies and road-mapping processes have been supported by multilateral organizations, such as IDB [2]. • CORFO contributed 50 MUSD in 2021, funding six projects [64, 180]. • In 2022, the Ministry of Energy, in coordination with the Budget Office (DIPRES), proposed creating the "Program to Promote Green Hydrogen in Chile" with 2.044 BCLP to promote the industry's development [181]. Chile has also received approval from DIPRES to implement a program to allocate 1 billion CLP in public funds to demand-side projects [45, 94]. Chile's 2023 Budget includes 3.9 billion CLP for the Green Hydrogen Program, which includes initiatives such as the Green Hydrogen Accelerator and a fleet of RH2 taxis in the Magallanes Region [182]. • Several multilateral organizations (such as IDB, World Bank, European Union, and KfW) will assist in deploying other funding vehicles to accelerate development of the RH2 economy. At COP27, an agreement was reached with the World Bank for an investment loan of 150 million USD in 2023 and 200 million USD in a second phase. Similarly, an investment loan of 400 million USD was announced through the IDB [183]. The IDB announcement was finally approved in June 2023 [184]. These agreements ultimately converged into a “facility” program, managed by CORFO, with a total of 1 BUSD. Operation will begin in the second half of 2024, aiming to leverage an investment of 12.5 BUSD [65]. • Antofagasta launched a 120 MCLP fund to develop public goods that enhance (1) the development of the RH2 industry in the region and (2) the circular economy applied to solar energy in the Antofagasta Region [45, 94].

Chile

Projects and initiatives	Financing and investment	• Feasibility studies and road-mapping processes have been supported by multilateral organizations, such as IDB [2]. • CORFO contributed 50 MUSD in 2021, funding six projects [64, 180]. • In 2022, the Ministry of Energy, in coordination with the Budget Office (DIPRES), proposed creating the "Program to Promote Green Hydrogen in Chile" with 2.044 BCLP to promote the industry's development [181]. Chile has also received approval from DIPRES to implement a program to allocate 1 billion CLP in public funds to demand-side projects [45, 94]. Chile's 2023 Budget includes 3.9 billion CLP for the Green Hydrogen Program, which includes initiatives such as the Green Hydrogen Accelerator and a fleet of RH2 taxis in the Magallanes Region [182]. • Several multilateral organizations (such as IDB, World Bank, European Union, and KfW) will assist in deploying other funding vehicles to accelerate development of the RH2 economy. At COP27, an agreement was reached with the World Bank for an investment loan of 150 million USD in 2023 and 200 million USD in a second phase. Similarly, an investment loan of 400 million USD was announced through the IDB [183]. The IDB announcement was finally approved in June 2023 [184]. These agreements ultimately converged into a “facility” program, managed by CORFO, with a total of 1 BUSD. Operation will begin in the second half of 2024, aiming to leverage an investment of 12.5 BUSD [65]. • Antofagasta launched a 120 MCLP fund to develop public goods that enhance (1) the development of the RH2 industry in the region and (2) the circular economy applied to solar energy in the Antofagasta Region [45, 94]. • Start-Up Ciencia-ANID promotes the growth and early-stage strengthening of science-technology-based companies in Chile. In 2022, the total subsidy was 7.2 BCLP; 120 MCLP for each project. 60 projects were eligible [185]. • The Ministry of Energy submitted two applications to channel funds (around 400 MCLP) from ANID to develop technological solutions for the retrofitting of fossil-fuel-based railway and maritime transport for RH2 and the DC-DC coupling of renewable generation and electrolysis facilities [45, 94]. • The Chilean Agency for Energy Sustainability’s tender for a Green Hydrogen Accelerator delivered 300 MCLP to assist the implementation of demand-side projects. • Corfo has launched a technological program to use and adopt H2 in industry to promote developments or technological adaptations. Benefits of up to 3,500 MCLP will be granted. This non-reimbursable subsidy covers up to 60% of the program's total cost [186]. • Other initiatives are (1) "Fondo Bilateral para el Desarrollo en Transición Chile-Unión Europea": 340,000 USD for pre-investment studies, (2) "Agencia de Sostenibilidad Energética": 360,000 USD (first call) and 950,700 USD (second call) for pilot projects, (3) Low Carbon Business Action" and European Union: A business platform for green technologies, (4) “Bundesministerium für Wirtschaft und Energie": Developing supply chains between Germany and other countries, and (5) “H2-Uppp program”, commissioned by GIZ, which collaborates with private companies through formal partnerships to implement pilot projects in RH2 and power-to-X. The public contribution may include measures worth up to 2 million EUR [2, 45, 94, 187].
	Collaboration	• National alliance: H2 Chile-Chilean Hydrogen Association [188]. • Regional alliances also exist. For example, in 2021, the Strategic Green Hydrogen Alliance for Bío Bío was announced; the University of Concepción leads it with the participation of companies, higher education institutions, civil society, and the government [189]. An H2 association for Antofagasta was announced in 2022, [190] and another for the Magallanes Region in March 2023 [191]. • As for international cooperation, GIZ has been commissioned to conduct studies for developing H2 in the country [192]. In March 2023, the Energy Partnership between Chile and Germany was extended [193]. Moreover, in March 2023, Alta Ley Corporation and SAMMI presented the First Binational Green Hydrogen Roadmap for Mining in Chile and Peru [95].
H2 potential	H2 production	• H2 could be produced locally and competitively in northern Chile thanks to high-quality solar resources and in southern Chile due to the available wind resources [2]. The country can potentially produce 160 Mt RH2/year [20]. • H2 would contribute 24% to the emissions reduction target by 2050, with a projected total consumption of 600 kt/year [194]. • In 2022, CORFO signed agreements to finance the development of Chile's first industrial-scale RH2 production plants. Once installed in 2025, the projects would have a total electrolysis capacity of 388 MW and produce over 45 kt RH2/year [64, 180, 195].
	H2 application and demand	• Chile has a large and diversified industrial sector. The country's potential is to explore options for low-carbon H2 in existing and new end uses, leveraging existing industrial capabilities and value chains [2]. • Six prioritized domestic areas: (1) Oil refineries (green for grey H2), (2) local renewable NH3 production, (3) blending into residential gas grids, (4) mining haul trucks, (5) heavy-duty on-road trucks, and (6) long haul autonomy buses [20, 45, 94]. • Moreover, H2 can be used in forklifts operating in mines, industries, and ports [20, 45, 94, 196]. RH2 could also be used at the airport to supply aircraft [197]. • The mining industry has experienced a 30% deterioration in ore grades over the last 15 years. However, copper requirements could grow to support the deployment of clean energy technologies. H2 uses in mining infrastructure are unlikely to become widespread by 2030 beyond a few demonstration projects but could significantly impact emissions in the medium- and long term. Moreover, non-stationary use in mining has been identified as a crucial future demand sector for low-carbon H2 based on the development of hybrid diesel/ H2 mining trucks [2]. • As a result of the RH2 demand and applications, workshops organized by H2 Chile and the Ministry of Economy, in the context of the RH2 Industry Development Committee, suggested that applications linked to land transportation, the mining industry, and gas blending could be the most relevant considering different criteria [198].



Chile

H2 potential	Infrastructure, transport, and storage	• The NG infrastructure (North, Central, Central-south, and South regions) is developed. NG is transported in four macro zones: Antofagasta, Metropolitan- Valparaíso, Biobío, and Magallanes. Moreover, transmission pipelines between the far south and far north are underutilized. Thus, transmission pipelines could be attractive for repurposing in the long term [2]. Chile also has international gas pipelines with Argentina. The technical specifications of the pipelines can be consulted in a study by GIZ [199], and the available gas pipelines can be looked up in "Energía Maps" [200]. However, no reference covers all gas pipelines for distribution; only some are summarized in the GIZ study [199]. Injecting H2 into the NG grid at low percentages is feasible due to the transport network's high operating pressures and the embrittlement effect risk. Also, the tolerance of the network's connected equipment must be considered [199].
	H2 export and trade	• Significant volumes of low-carbon H2 could be exported [2]. As of 2025, Chile will want to activate the industry and develop exports (renewable NH3 and RH2). In 2030, the estimated Chilean export market will be 2.5 BUSD/year (2 BUSD- renewable NH3; 0.5 BUSD-RH2); 16 BUSD/year in 2040 be (5 BUSD- renewable NH3; 11 BUSD-RH2), and 24 BUSD/year in 2050, (5 BUSD- renewable NH3; 19 BUSD-RH2) [20]. • The goal is to export to East Asia (Japan/Korea), North America (USA), and Europe through large-scale consortia [20, 45, 94]. Chile has signed several MoUs with strategic ports in Europe and Asia: Antwerp-Bruges (2021); Singapore (2021); South Korea (2021), and Hamburg (2022) [201, 202, 203]. In March 2023, an MoU was renewed with the Port of Rotterdam and the Strategic Cooperation Green Hydrogen Agenda 2023-2025 was agreed with Dutch authorities, which refers to the connections through maritime corridors and port infrastructure for the RH2 industry [204, 205]. Finally, the Chilean Ministry of Energy; the Ministry of Climate and Energy Policy of the Netherlands; the Illustrious Municipality of Mejillones and the Port of Angamos signed a declaration to promote and strengthen cooperation and economic, scientific, and technological exchanges between countries [206].
	CCUS potential	• CCUS potential is low [2].
	Human capital	• E-fuel projects are under development. For example, the Haru Oni project combines CO2 from direct air capture and electrolytic H2 to produce synthetic methanol and gasoline [2]. • Chile has the potential to generate at least 22,000; 87,000; and 94,000 jobs by 2030, 2040, and 2050, respectively. When considering regional productivity factors, these values could increase to 68,000; 251,000; and 255,000 jobs by 2030, 2040, and 2050, respectively [103]. • Corfo has called for training institutes to develop training programs considering the circular economy, sustainable business models, carbon emissions, and SDGs [203]. Moreover, ANID has been promoting "advanced human capital formation" to address possible skill gaps in the future [2]. • In March 2023, the Subsecretary of Energy and ChileValora published three new RH2 professional profiles (H2 plant operator, supervisor, and maintainer) [104, 208].
	LCOH (2025)	• 1.7-2.6 USD/kg RH2 [2]
	LCOH (2030)	• 1.3-1.8 USD/kg RH2 [2] <1.5 USD/kg RH2 [20]
	LCOH (2040)	• 1.0-1.3 USD/kg RH2 [2]
	LCOH (2050)	• 0.8-1.1 USD/kg RH2 [20]

Colombia

Current context	Renewable energy availability, installations, and regulation	• The country has high-quality wind and solar resources and therefore competitive renewable electricity [2]. • Regions such as La Guajira have a wind speed of 9 m/s (twice the world average) and solar radiation 60% higher than the world average [209]. The wind power plant factor can achieve 63% in La Guajira, while solar resources can achieve 21% in Caribe Norte and Andes Norte [22]. • The share of RE in the national energy matrix will go from <1% in 2018 to 12% in 2022 [210]. Colombia is among the ten countries that concentrate 46% of the international water supply suitable for hydroelectric generation. • Hydropower provides over 60% of electricity generation [2]. As of December 2018, the installed generation capacity in the National Interconnected System was 17,312 MW, of which 68.4% corresponded to hydroelectric generation, around 30% thermal (13.3% with NG; 7.8% with liquid fuels, and 9.5% with coal) and around 1% NCREs (wind, solar, and biomass) [10]. Since August 2018, the main objective of energy policy has been to increase from 50 MW of installed capacity to 1,500 MW, which was surpassed through two auctions held in 2019 and the development of large self-generation projects by companies such as Ecopetrol and EPM [210]. Moreover, nonconventional energy projects accumulate 2,500 MW (50 times the capacity in 2018) [210]. • The share of RE in the national energy matrix will thus rise from <1% (2018) to 12% (2022) [210]. • Related to regulations, Law 1,715 (2014) integrates NCREs into the National Energy System, while Decree 570 (2018) regulates public policy guidelines for the long-term contracting of electricity generation, and Law 1,955 (2019) issues the National Development Plan 2018-2022. Lastly, CONPES 3934 (2018) establishes the Green Growth Policy [82].
	Emissions and emissions reduction commitments	• 303 Mt CO_2eq were emitted in 2018. Livestock, agriculture, and land use change represent 59% of emissions, followed by the energy sector (31%), waste (7%), and industrial processes and product uses (3%) [13, 211]. • In 2020, Colombia publicly pledged to achieve carbon neutrality by 2050 [2, 22]. A maximum of 169.44 million tons CO_2eq in 2030 has been defined (equivalent to a 51% reduction in emissions compared to projected 2030 emissions in the reference scenario). Emissions will start to fall between 2027 and 2030, tending toward carbon neutrality by mid-century [13]. • Colombia committed to reducing emissions by 2.5-3 Mt CO_2 in 2020-2030 due to the adoption of RH_2 [22].
	Transport sector	• Announced targets and ambitions for deploying electromobility exist, focusing on LDVs and urban buses. Targets for the sale of zero-emissions urban buses (10% of sales in 2025, 100% by 2035) include BEVs and FCEVs [2]. The National Electromobility Strategy presents the roadmap to promote electromobility for land, rail, and river transport. Colombia aims to incorporate 600,000 electric vehicles by 2030 [212]. Moreover, demand for 1,500-2,000 light fuel cell vehicles and 1,000-1,500 vehicles for the heavy transport segment is expected to be related to H_2 goals [22].
	Carbon pricing	• Colombia has a carbon tax (2017) of 5 USD/t CO_2e, which applies in any of three stages associated with the fossil fuel distribution chain: (1) when it is sold in national territory, (2) when the fuel's producer fuel extracts it for its own consumption, (3) when fuel is imported. • Law 2,169 (December 2021) establishes that as of 2023, half of the revenues from the tax will be used for coastal erosion management, conservation of water sources, and the protection of ecosystems. The other half will be to finance the Illicit Crops Substitution Program [22, 114].
	Current H_2 production	• The country is considering implementing an ETS (2021) [2] and the Government is currently analyzing its design. The Climate Action Act (December 2021) consolidates the commitments presented in Colombia's NDC and sets the goal of implementing the ETS by 2030. This law has also established an obligation for legal entities to report direct and indirect GHG emissions, following the criteria set by the Ministry of the Environment and Sustainable Development [114]. • Current H_2 production is about 155 kt (90% gray and 10% blue H_2). H_2 is mainly produced by steam reforming with NG [211].
	Current H_2 use	• Oil refining, chemicals-NH_3, iron and steel-blast furnace, cement [2]. Other uses include mining and food industries (fats and oils) and float glass production [2, 22]. • Currently, 84% of the H_2 is produced and consumed by the refinery sector, 12 % in the fertilizer industry, and 4 % in other industries, such as hydrogenated fats [211].
H_2 policy	H_2 policy plan, roadmap, or strategy	• Yes: National H_2 roadmap (published, 2021) [22]. • The Ministry of Energy developed the H_2 roadmap with the IDB's support. Blue H_2 is the most favorable option in the short term, mainly if the existing industrial infrastructure can be used. RH_2 can be a competitive alternative in regions with the best wind resources (such as North Caribbean) starting in 2030 and blue and green H_2 will coexist between 2030-2040. After 2035, blue H_2 will be more competitive than grey H_2 and RH_2 will be the most competitive alternative as of 2040, creating a new export market. • In addition to the 2030 electrolysis and H_2 production capacity, the roadmap defines several other goals: the number of fuel cell vehicles (light and heavy), the number of H_2 stations, the percentage consumption of low-emission H_2 in the industrial sector (40%), an investment of 2.5-5.5 BUSD and CO_2 abated (2.5-3 Mt of CO_2 in 2020-2030). It also defines the work streams [22], such as estimation of the export potential for green and blue H_2, describes the regulatory enablers and incentives needed for production, transportation, and use of RH_2 and blue H_2, and identifies stakeholder groups and entities related to H_2 implementation [82, 213]. • Currently, the Ministry of Energy and Mining is focused on implementing the actions of the first phase of the H_2 roadmap to create a solid market [211].

Colombia

H2 policy	H2 production goal (horizon)	• At least 50 kt of blue H2 (2030) [22].
	GW electrolysis goal (horizon)	• 1-3 GW of electrolysis (2030) [22].
	Regulatory framework	• The Ministry of Sciences published the tender "Sustainable energy and its contribution to mining-energy planning," which plans to develop issues related to reliable energy supplies and diversification of the energy matrix (prospective production and use of H2). The objectives to be achieved are: (1) carrying out a comprehensive analysis to identify how to incorporate H2 within the framework of Law 1,715 of 2014 (including its definition and possible classifications), (2) identifying the technologies associated with blue and green H2, given that Law 1,715 of 2014 mentions Nonconventional Energy Sources (FNCE), but not the technologies with which they can be used [82]. • Energy Transition Act, Law 2,099 (2021), establishes a practical fiscal framework for investment in nonconventional energy sources. Thus, RH2 is considered a nonconventional renewable energy source (FNCER) and can be produced from biomass, small hydroelectric plants, wind, geothermal, solar, or tidal power. Blue H2 is regarded as a nonconventional energy source (FNCE) produced from fossil fuels, adding CCUS. Also, under Law 2,099, the benefits of Law 1,715 (2014) will be applied to both for 30 years. Moreover, Law 2,099 extends the scope of action of the Fund for Non-Conventional Energies and Efficient Energy Management (FENOGE) to the financing or execution of viable projects in any link in the of low-emission H2 value chain [22]. • Decree 1,476 promotes innovation, research, production, storage, distribution, and use of H2 and sets the institutional framework to develop the regulation of the specific sectors that will use H2 [28]. • CONPES 4,118 document aims to develop the required infrastructure for exporting hydrogen and its derivatives and their use in decarbonizing the maritime sector [46].
	Other announcements	• The Mining Energy Planning Unit (UPME) developed the National Energy Plan, PEN 2022-2052, to meet the country's energy requirements. This document compiles different scenarios of hydrogen adoption in the country. The current agenda aims to install 3 GW electrolyzers by 2030 and 16.5 GW by 2050. It also considers the residual biomass potential for hydrogen production and the future market for blue hydrogen [82, 214]. • In February 2022, the Energy Transition Policy increased energy reliability and GHG reduction, with a 6-year application horizon (2022-2028), and H2 is a central part of it. Through this policy, the Government is analyzing new technologies to produce sustainable H2 through geothermal, biomass, and offshore wind [82]. • An analysis to determine the existence of natural H2 reservoirs is being conducted. • The Ministry of Energy, the Ministry of Science, and UPME are developing a study to identify the national potential for the production and commercialization of H2, its possible uses in different economic sectors, and its inclusion in the energy matrix [213].
Projects and initiatives	Total number	• 27 RH2 projects.
	R&D	• In line with its innovation, science, and technology strategy, Ecopetrol Group has joined forces with IDB, ANDI, iNNpulsa Colombia, the Cartagena Chamber of Commerce, SENA, and its Tecnoparques model, universities, and other organizations, to form the first Innovation and Technology Center in the Caribbean, which will be part of the country's “C-Emprende” network. This laboratory will propose solutions to the challenges of the energy transition and petrochemicals, with a particular focus on H2 [91]. • Moreover, the academic sector (U. La Sabana and Antioquia) has worked within the framework of the SÉNECA [2]. • Within the framework of the SENECA project, Universidad de Antioquia has developed technologies and studies for blending of hydrogen and hydrocarbons such as diesel, natural gas, propane, and carbon. • EAFIT University is developing a bioinspired PEM electrolyzer, which aims to use the mitochondria's geometry to improve energy efficiency on the electrolyzer's stacks.
	Financing and investment	• Law 2,099 updates current energy regulations, includes green and blue H2 as an FNCER and FNCE, respectively, and amends Law 1,715 of 2014, which provides incentives and tax benefits for investments in these sources. • Decree 895 (2022): H2 projects would have access to tax benefits. • Law 1,715 (2014) provides tax benefits such as (1) Deduction of up to 50% of income tax, (2) Exclusion of goods and services from VAT, (3) Exemption of tariffs, (4) Accelerated depreciation [57]. • Colombia will invest 1.5 million USD in 10 green and blue H2 projects. In addition to financing pre-investment studies, beneficiaries will be accompanied during project development. The international support obtained for this initiative includes the German Ministry of Economy and Climate Protection through GIZ and the Korean Government represented by the Korea Eximbank and allied experts in H2, such as Colombia Inteligente and NREL, with support from USAID. • CIF approved the country's Investment Plan to implement its Renewable Energy Integration (REI) Program with a package of up to 70 million USD. The Colombian Government prepared the plan under the leadership of the Ministry of Mines and Energy, and it will be implemented with the support of the IDB [216].
	Collaboration	• The Colombian Hydrogen Association is working together with the government and international collaborators to create supply and demand incentives and promote financing strategies such as specific funds for H2. • National alliance: Hidrógeno Colombia-Colombian Hydrogen Association [217], and the Chamber of Hydrogen ANDI-NATURGAS [218, 219]. • As for international collaboration, GIZ has also been consulted by the Colombian Government to make a specific contribution to H2 development [82].

Colombia

H2 potential

H2 production	• Oil, NG, and coal reserves could be used for blue H2 production [22]. Colombia is a major carbon producer in LATAM and one of the leading global exporters. Carbon reservoirs total over 4,500 Mt [90], while NG reservoirs are 2,949 Gpc (7.7 years) [89]. • In the medium- and long term, Colombia could supply domestic low-emission H2 demand. CCS technologies will be boosted in the coming years [22]. Ecopetrol's Strategic Hydrogen Plan has set a production target of 1 Mt of low-carbon H2 by 2040 and the H2 produced would be destined for export and domestic consumption. Estimates show that current H2 production from the refineries (10% blue + 90% gray) and other developments can provide the 1 Mt aspired to, distributed as follows: 40% RH2, 30% blue, and 30% white [215].
H2 application and demand	• Colombia has a large and diversified industrial sector. Oil refineries process more sour crude grades than in other countries, leading to higher H2 requirements per refined barrel of crude. The country's potential is to explore options for low-carbon H2 in existing and new end uses, leveraging existing industrial capabilities and value chains and decarbonizing current production [2]. • In the future (2020-2050), transport and industry will be the main sectors for H2 demand: 94% of total demand in 2030 (120 kt) will be related to industry; 49% of total demand in 2040 (790 kt) will be related to industry and 47% to transport; 64% of total demand in 2050 (1,850 kt) will be related to transport and 34% to industry. Moreover, 40% of total H2 demand in 2050 (740 kt) will be used to supply the production of derivatives, such as NH3 and synthetic fuels, thus reducing fertilizer imports and improving demand for transport (maritime and air) [22].
Infrastructure, transport, and storage	• Colombia has a developed NG infrastructure [2] and experience in the handling and transportation of gas [22].
H2 export and trade	• Significant volumes of low-carbon H2 would be exported [2]. In the long term, exports will be comparable in income to the country's current coal exports (over 5 BUSD). Colombia can become a H2 logistics hub due to its strategic geographical location and its transport, distribution, and trade networks [22]. • The country also aims to export 3.2 Mt RH2/year by 2050 as it is near to some of the busiest ammonia trading routes [100]. It already has two ports for trading ammonia, which are placed in the cities of Barranquilla and Cartagena [101].
CCUS potential	• CCUS potential is low due to limited experience or initiatives [2]. • There is an industrial cluster in the Port of Cartagena [2].
Human capital	• Colombia considers using the existing human capital in sectors impacted by the energy transition process. Thus, updating knowledge and skills is recognized as essential to enable a just transition. The role of H2 as a transformation tool will be evaluated, allowing the relocation of workers in the RE or H2 sectors. • 7,000 to 15,000 direct and indirect jobs are expected to be created in 2020–2030, thanks to the development of H2 production, demand, and transport projects [22].
LCOH (2020)	• 1.9-2.5 USD/kg H2 gray H2 • 2.4 USD/kg H2 blue H2 • 2.8-6.6 USD/kg H2 RH2 [22]
LCOH (2030)	• 2.2-3.0 USD/kg gray H2 [22] • 2.4 USD/kg blue H2 [22] • 1.7 USD/kg RH2-3.7 USD/kg RH2 [22]
LCOH (2040)	• 2.5-3.5 USD/kg H2 gray H2 [22] • 2.4-2.5 USD/kg H2 blue H2 [22] • 1.8-3.0 USD/kg H2 RH2 [22]
LCOH (2050)	• 2.9-4.4 USD/kg H2 gray H2 [22] • 2.4-2.5 USD/kg H2 blue H2 [22] • 1.5-2.4 USD/kg H2 RH2 [22]

Costa Rica

Current context	Renewable energy availability, installations, and regulation	• The national energy matrix is almost 100% renewable [47, 87]. As of December 2022, Costa Rica had accumulated six years in which 98% of the country's electricity was generated with RE. Hydropower provides >60% of electricity generation [2]. According to ICE, renewable electricity generation has been obtained mainly from water (73% in 2022), wind (11.5% in 2022), geothermal (13.6% in 2022), biomass, and solar power (less than 1.5% in 2022) [8]. The nation has the third-largest geothermal generation capacity in the continent, with 262 MW. It has 18 wind farms in Guanacaste and San José [8]. Electricity demand is met, and a surplus is produced [47]. A total of 6,213 GWh of electricity was generated in the first half of 2022, of which 324 GWh were exported to the Regional Electricity Market (MER) [220]. Nevertheless, in 2021, electricity accounted for just 22% of energy consumption, while fossil fuels accounted for 68%, mostly for transport and industry [2, 221]. • Solar and wind resources have a high but as-yet unexploited potential [47]. • General regulations related to RE [47]: the National Technical regulations [222], National Regulation [223], Regulation of the Rational Use of Energy and its amendments, Law to Encourage the Development and Use of renewable Energy Sources [224], National Energy Plan (PNE) [225], and Renewable Energies and Electromobility [226].
	Emissions and emissions reduction commitments	• Emissions are mostly related to the transport sector [2]. Due to fossil fuel consumption, transport and industry are responsible for 42% and 9% of emissions, respectively [2, 221]. • Costa Rica was the first LATAM country to announce a net-zero emissions target for 2050 (2019) [2, 87, 90, 228]. It has pledged to reduce between 500,000 and 650,000 tons of CO2eq per year, to be achieved by 2030, by adopting H2 in the country [24]. H2 will be part of the technologies contemplated in the National Decarbonization Plan 2018-2050. Moreover, the government signed an agreement with IRENA (2021) to consolidate this plan through an investment roadmap [2, 87, 227, 228].
	Transport sector	• The transportation sector accounts for 65% of Costa Rica's energy consumption and uses mostly fossil fuels imported for 2 BUSD annually [87]. Targets and ambitions for the deployment electromobility have been announced, focusing on LDVs and urban buses. • Costa Rica has had the first LATAM FCEVs (1 bus and 4 LDVs) since 2011, using H2 produced from renewable electricity and supported by LATAM's first H2 refueling station [2].
	Current H2 production	• 100 kW of electrolysis in 2022 [229].
	Current H2 use	• Cement [2], food (hydrogenated fats), medical devices (unspecified use), and steel (galvanizing process) sectors [24]. • The demand is met by medium-capacity electrolyzers, which are fed with energy from the electricity grid, accumulating 475 kg/day, or the equivalent of about 170 tons H2/ year, which can already be considered green or low-emission as it uses the mostly renewable electricity matrix [24].
H2 policy	H2 policy plan, roadmap, or strategy	• Yes: National H2 strategy (published, 2023) [24]. • The National H2 Strategy plans to activate demand, mainly in the transportation sector. H2 will also contribute to replacing fossil fuels in industry (especially LPG). In addition, the strategy presents an action plan whose main objective is to promote the initial phase of H2 adoption. Its main focuses are creating enabling conditions, decarbonizing the transport and industry sector, and developing a technology hub and H2 export [24].
	H2 production goal (horizon)	• The H2 production goals are related to the installed capacity of electrolyzers (150 – 500 MW by 2030) [24].
	GW electrolysis goal (horizon)	• 0.15- 0.5 GW of installed and developing electrolysis capacity by 2030 [24].
	Regulatory framework	• In August 2018, the Ministry of the Environment and Energy, MINAE, enacted a directive convening a National Hydrogen Committee to develop an Action Plan for the research, production, and sale of hydrogen, designating the Energy Subsector Planning Secretariat (SEPSE) as its secretariat [47]. Thus, the National Technical Committee for Hydrogen was created, responsible for adapting the required international regulations and standards for the design and operation of systems for the production, storage, transportation, and use of hydrogen. It has nationalized standards such as INTE / ISO 14687: 2020 and INTE / ISO 22734: 2020, which initiate an enabling environment for H2 applications [47]. In 2021, a decree to promote "the development of an RH2 economy " was published [47]. The list of assets exempted by Law 7,447 on the Regulation of the Rational Use of Energy was updated, including H2-related equipment (Decree N°43,095, 2021) [229]. The H2 tax incentive bill is also under discussion in Congress [49].
	Other announcements	• The VII National Energy Plan 2015-2030 considers a proposal for introducing H2 vehicles, among other technologies, in addition to the promotion of research on the production and use of alternative fuels, including H2 [47]. • The roadmap for H2 use in transport (2018) establishes a legal framework for public entities to develop H2 activities and identifies the public vehicle fleet as an initial focus. It enhances efforts to replace imported fossil fuels with renewables, reduce emissions, and improve energy security. The roadmap also identifies road freight transport as a potential focus area for H2 development through the Central American Integration System (SICA) [2, 47, 230]. • In 2019, IDB Lab started a project titled "The Road to Decarbonization: Promotion of the Hydrogen Economy in Costa Rica" [229]. • In 2020, a study prepared by ISF proposed a decarbonization roadmap for Costa Rica [231]. • An agreement with IRENA (2021) was established to work on an investment roadmap that will promote RH2 production [232]. • In June 2021, the final version of the IDB-funded RH2 market research was published, which was used as a main input for the National Green Hydrogen Strategy [48].

Costa Rica

Projects and initiatives	Total number	• 7 RH2 projects.
	R&D	• GIZ project "MiTransporte," financed by the German Environment Ministry, BMU, and the GIZ Innovation Center initiative in Costa Rica, has promoted research about the potential of H2 production and use [47]. • Between 2012 and 2014, Cummins, EARTH University, and Ad Astra developed and tested a prototype generator set to run on blends of RH2 and biogas. Between 2015 and 2017, Cummins and Ad Astra jointly developed a 5-kW compact wind turbine to test the viability of this technology as a component of renewable H2 systems [229]. • IDB supports feasibility studies and road-mapping processes [2]. • In 2021, the country applied to the NAMA Facility's Ambition Initiative with a NAMA Support Project titled "Green Hydrogen for a Decarbonized Economy." This effort was led by GIZ on behalf of the Ministry of Environment and Energy (MINAE) and was selected to move on to the Detailed Preparation Phase (DPP) in October 2021.This phase is ongoing. If approved, the project will receive an investment of 25 million EUR. The project involves installing and operating a hydrogen refueling station and ten RH2-powered fuel cell trucks in the second half of 2023 [229].
	Financing and investment	• Investment of between 1 BUSD and 2.5 BUSD is expected, to be deployed between the strategy's release and 2030, which may be executed indistinctly for production, consumption, or deployment of H2 logistic infrastructure projects [24].
	Collaboration	• National alliance: the Costa Rican Hydrogen Alliance [234] and the Costa Rican Hydrogen Association. • The alliance, with the support of the IDB Lab project "Road to Decarbonization – Promoting the Hydrogen Economy in Costa Rica," prepared several studies on the potential and possible use of H2 in different applications; all completed studies are available [234].
H2 potential	H2 production	• According to Hinicio, Costa Rica would have a production potential of almost 6 Mt, equivalent to 8.5% of global demand [87].
	H2 application and demand	• The country addresses emissions beyond the power sector, such as the transport sector, especially road freight transport [2]. Thus, RH2 could free the country from its oil bill [87]. • The H2 demand forecast for Costa Rica in 2030 is between 18 and 20 ktH2/year, which could reach 420 ktH2/year by 2050 [24]. Hinicio projects demand of over 600 kt of RH2 per year by 2050, with over 90% going to the transportation sector [87].
	H2 export and trade	• The RH2 market could contribute 484 million USD to the economy, about 0.3% of projected GDP in 2050 [87].
	Human capital	• 20,000-30,000 direct and indirect jobs could be generated by adopting RH2 (including developing renewable projects) [24].
	LCOH (2025)	• 2.1-5.8 USD/kg RH2 [24]
	LCOH (2030)	• 1 USD/kg gray H2 [107] • 2-4.8 USD/kg RH2 [107, 24]
	LCOH (2040)	• 2.2 USD/kg gray H2 [107] • 1.5-2.2 USD/kg RH2 [107]
	LCOH (2050)	• 2.8 USD/kg gray H2 [107] • 1.2-1.9 USD/kg RH2 [107, 24]

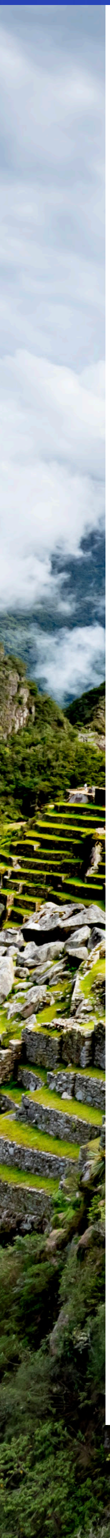
Mexico

Current context	Renewable energy availability, installations, and regulation	• Mexico has high-quality wind and solar resources and therefore competitive renewable electricity [2]. • According to the Government, there are thousands of unexplored TWh of solar and wind energy [84] available. The Energy Transition Law establishes a goal of 35% renewables by 2024 [84], when over 19 GW of new and replacement generation capacity will be added – half of it solar PV [84]. • The renewable potential is 864-4,094 TWh/year [84]. Furthermore, the Renewable Energy Outlook (2016-2030) states that Mexico has the proven potential to generate 4,7 TWh/year from hydropower plants, and, according to the National Renewable Energy Inventory, INERE, there is 16 TWh/year of additional potential for small hydro between 2021 and 2030 [84]. • NG accounted for nearly 40% of the national energy supply mix in 2019 (largely imported from the US), while solar PV and wind combined contributed just 3% [84]. • Of the total installed electricity generation capacity (79,599 MW), 29.4% is RE (geothermal, wind, hydroelectric, photovoltaic, biomass) [6]. Clean generation, primarily hydropower and wind, accounted for 23% of total power generation in 2019 [84]. NG accounted for 60% of Mexico's total electricity generation. • As for regulatory aspects, since the Energy Reform, privately owned generators and the Federal Electricity Commission (CFE) can supply users, though the Mexican state still owns electricity transmission and distribution services. However, the state can celebrate contracts with the private sector to operate transmission and distribution grids [84]. Moreover, the Electricity Industry Act (2014) defines clean energy, including wind, solar, tidal, geothermal, bioenergy, biogas, and H2. In the latter's case, the minimum efficiency should not be less than 70% of the lower heating value of the fuels used [235]. For its part, the Energy Transition Act (2015) mandates that 35% of electric power generation must come from clean energies by 2024. Likewise, it defines its planning instruments as: (1) the Transition Strategy to promote the use of cleaner technologies and fuels, (2) the Special Program for Energy Transition, and (3) the National Program for Sustainable Energy Use (PRONASE) [29].
	Emissions and emissions reduction commitments	• The results of the update by the National Inventory of Greenhouse Gas and Compound Emissions (INEGYCEI) show that Mexico emitted 736 million tons of CO2eq in 2019, corresponding to the sum of GHGs. The sector that contributes the most is the energy sector, with 64% of emissions, mainly related to the consumption of fossil fuels, followed by AFOLU with 19% of emissions; the Industrial Processes and Product Use sector (10%) and lastly the waste sector (7%) [14]. • The General Climate Change Act (2012) establishes that different sectors must obligatorily report their direct and indirect emissions of GHG or compounds from all facilities exceeding 25,000 t CO2eq. Moreover, the Energy Transition Act annually reduces between 80 and 100 Mt of CO2. • Moreover, the General Climate Change Act defines its planning instruments as: (1) the National Climate Change Strategy, (2) the Special Climate Change Program, and (3) the Federal State Programs. Likewise, it recognizes the country's NDC. • Currently, net-zero pledges are under discussion. Mexico presented an update of its NDC: it proposed GHG reductions of up to 35% by 2030 compared to the business-as-usual scenario (versus a 22% reduction established in its previous submission in 2020). This commitment could grow to 40% if external support is secured (previous conditional target was of 36%) [19].
	Transport sector	• Road freight transport is the main mode for importing and exporting goods [2]. • The National Institute of Electricity and Clean Energies (INEEL) and academia developed an FCEV prototype for a small vehicle [2]. • P4G-Getting to Zero Coalition Partnership identifies opportunities to promote sustainable shipping in the country, focusing on low-carbon fuels, vessels, and port infrastructure (2020) [2]. • Mexico is also a major trading hub between North and South America and has capitalized on its access to the Pacific and Atlantic Oceans. Its top trading partners include the US, China, and Canada. Mexico is a major exporter of automobiles and their related parts, oils, and other fuels. Most maritime vessel traffic is dominated by offshore service vessels, but the largest share of fuel usage (35%) is attributed to container vessels [87].
	Current H2 production	• The Mexican carbon tax is an excise tax under the special tax on production and services. The tax applies to the sale of fossil fuels throughout national territory or their import, with NG exempted. It is not a tax on the fuels' full carbon content, but on the additional CO2 emission content compared to NG. Taxpayers can pay this tax by delivering carbon credits when they originate from projects developed in Mexico and endorsed by UNFCCC. The carbon tax is 0.42-4 USD /t CO2eq [114]. • The carbon tax is also complemented by an ETS pilot (2020) [2], which started operating in 2020. It covers direct CO2 emissions from entities in the energy and industry sectors that generate at least 100,000 t CO2/year and account for 40% of the nation's GHG emissions) [114]. • H2 production is 700 kt (2019), mainly from unabated fossil fuels [2]. • H2 for use in PEMEX is produced by third parties as a byproduct of other chemicals and in dedicated facilities [87].
	Current H2 use	• Oil refining, chemicals-NH3, iron and steel-DRI, iron and steel-blast furnace, cement [2, 87]. • 60% of total H2 demand is attributed to oil refining [2]. The largest consumer is PEMEX [87]. The steel industry, where H2-rich syngas is used for the direct reduction of iron, is the second largest consumer in the country. Moreover, ammonia is already used in agriculture, which is mainly imported [87].
	H2 policy plan, roadmap, or strategy	• No: Nonexistent, but there are private initiatives [27, 28]. • Though the country lacks a public initiative, in 2022 the Mexican Hydrogen Association presented the study "Green Hydrogen: The Energy Vector to Decarbonize Mexico's Economy" and a Roadmap to boost this industry [27].

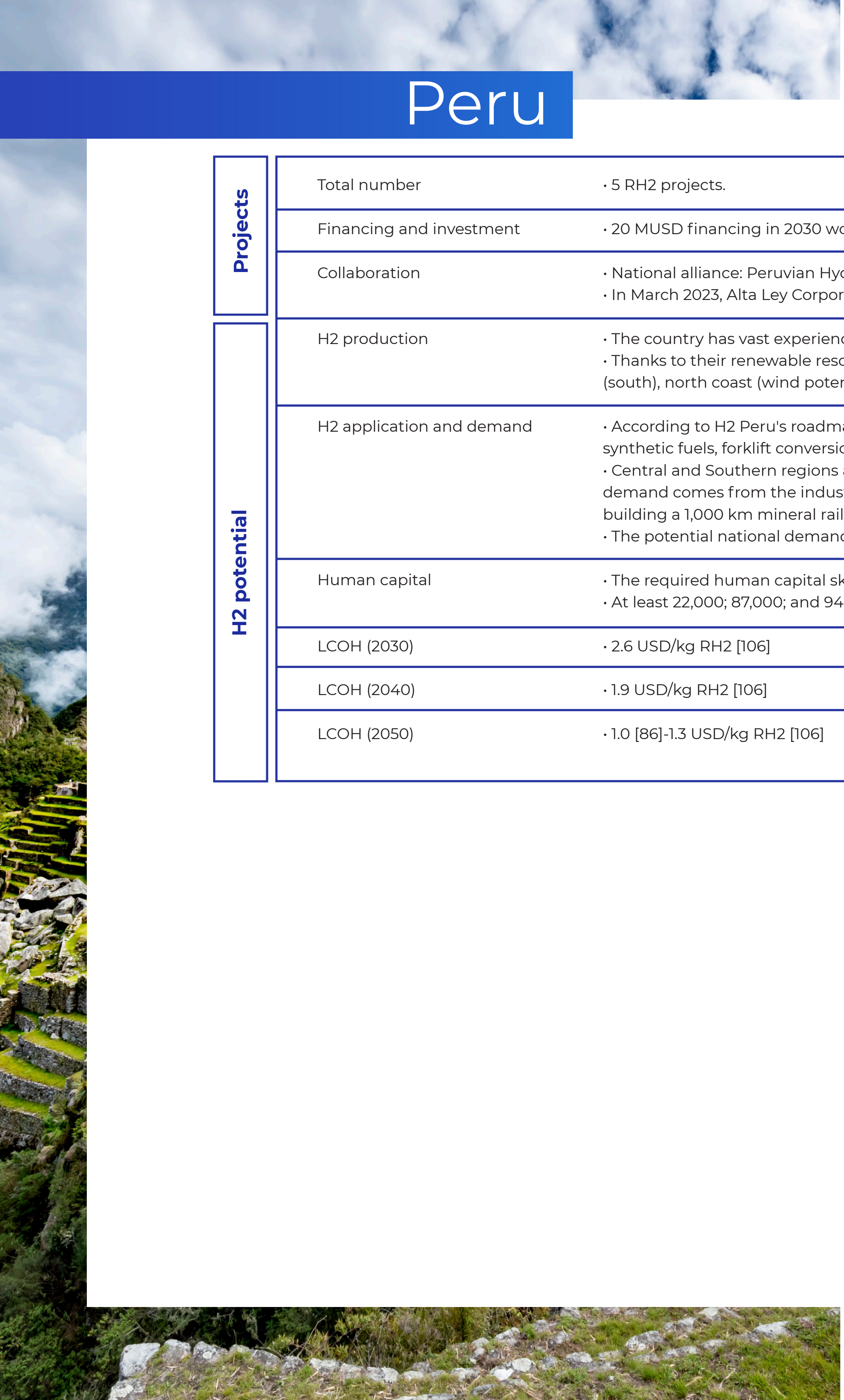
Mexico

H2 policy	Regulatory framework	• The Strategy to Promote the Use of Cleaner Technologies and Fuels mentions gasification for H2 production as an efficient technology in the use of bioenergy [27]. • The Energy Sector Program highlights the option of exploring H2 use [27]. • Guidelines for the granting of CELs indicate the use of H2 as an accredited unit [27]. • Lastly, a 2021 update to the Energy Industry Act includes H2 as clean energy for combustion or its use in fuel cells, provided the minimum efficiency established by the Energy Regulation Committee (CRE) is fulfilled, as well as the emissions criteria established by the Secretariat of the Environment and Natural Resources (SEMARNAT) regarding its life cycle [27].
	Other announcements	• The Mexican Hydrogen Association has approached the Chamber of Deputies and formally determined to continue working to develop a national H2 strategy, an approach that is also expected with the Senate [236]. • The National Electricity System Development Program 2023-2037 promotes the role of RH2 for electricity generation and blending [237].
Projects	Total number	• 9 RH2 projects
	Financing and investment	• Adoption of zero carbon propulsion technologies at Mexico's ports could attract investment of 130-188 billion MXN in onshore infrastructure by 2030 [87].
	Collaboration	• National alliance: Mexican Hydrogen Association [238].
H2 potential	H2 production	• The demand for RH2 is estimated to start in 2025, increasing to 230 kt by 2030 and 2,700 kt in 2050. For this, 79 GW of renewable capacity and 51 GW of electrolysis must be installed by 2050 [239].
	H2 application and demand	• Mexico has a large and diversified industrial sector. Oil refineries process more sour crude grades than in other countries, leading to higher H2 requirements per refined barrel of crude. Moreover, the country's potential is to explore options for low-carbon H2 in existing and new end uses, leveraging current industrial capabilities and value chains and decarbonizing existing production [2]. • H2 and NH3 could be used for large commercial vessels such as tankers, containers, and bulk carriers [87], in addition to industrial thermal applications like mining. Moreover, RH2 could replace gray H2 as feedstock in the chemical and food industries and diesel in heavy-duty mining trucks. It could replace NG used as a chemical reagent in reducing steel, copper, and other metal ores. • Mining trucks and ore reduction are attractive applications as they could account for nearly 80% of the projected demand by 2050. Synthetic fuels or e-fuels could represent the highest share of H2 demand in state-owned businesses (PEMEX and CFE), followed by electricity generation with H2 [96]. • The National Electricity System Development Program 2023-2037 proposes 1,024 MW of combined cycle capacity to progressively use a blend of 70% natural gas and 30% RH2 for electricity generation. Moreover, gaseous RH2 can be considered for blending in the gas grid, which requires adapting part of the natural gas infrastructure [237].
	Infrastructure, transport, and storage	• In 2019, NH3 and urea production stood below installed capacity due to competition from external producers and difficulties securing gas supplies. Suspended NH3 production restarted at the Cosoleacaque petrochemical complex in 2020 [2]. • Moreover, the country has a developed NG infrastructure [2] and handling and storage experience [87]. • Using H2 in turbines could be part of energy storage systems, which convert excess energy into H2 through electrolysis and then reconvert to on-demand electric power in the turbine. In the national electricity system, energy storage with RH2 could increase RE generation by 2% by 2050, and CFE could power 670 MW of thermal power plants using RH2 in an amount comparable to the H2 demand of PEMEX in 2018 [96].
	H2 export and trade	• Significant volumes of low-carbon H2 would be exported [2]. Mexico could be the second most competitive exporter to Asian destinations and the third to European markets due to its low cost of H2 production and its privileged geographical position. • Moreover, the country could become a leading manufacturer of FCEVs and be competitive in the manufacture of electric H2 turbines, storage tanks, compressors, and pipelines [239]. • The RH2 industry could have a 46 BUSD impact on GDP between 2025 and 2050 [239].
	CCUS potential	• CCUS potential is medium because the feasibility studies and pilot programs initiated are applying CCUS to gas-fired power generation, with support from the World Bank. However, experience is limited [2]. Planned refineries and modernizations could include CO2 capture from H2 and power production [2].
	Human capital	• 340,000 jobs would be created between 2025 and 2050 [239].
	LCOH (2020)	• 4.75 USD/kg RH2 [96]
	LCOH (2030)	• 2.55-3.25 USD/kg RH2 [96]
	LCOH (2040)	• 1.76-2.19 USD/kg RH2 [96]
	LCOH (2050)	• 1.22-1.50 USD/kg RH2 [96]

Peru

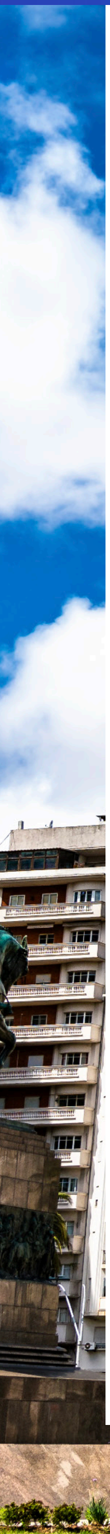


Current context	Renewable energy availability, installations, and regulation	• Northern and southern Peru have available wind resources and low electricity prices for the industrial sector. Moreover, the south has solar potential. • The country has a potential of 100 GW from hydroelectric, solar, and wind sources [240]. The power from renewable sources could reach 15,760-21,330 MW in 2050 [241]. • Until 2002, hydropower represented 85% of the total electricity generated in the country. However, with the development of Natural Gas production in Camisea, most of the newer generation plants use NG. According to the Energy and Mining Investment Oversight Agency, OSINERGMIN, in 2021, Peru had an electricity generation capacity of 12,675.41 MW. • The energy matrix is made up as follows: (1) 54.24% thermoelectric, (2) 39.78% hydroelectric, (3) 3.25% wind, (4) 2.25% solar, and (5) 0.48% biomass. Perú has 123 power plants, distributed as follows: seven wind, 74 hydroelectric, eight biomass, 27 thermoelectric, and seven solar [240]. • The regulatory framework that promotes the use of RE can be summarized as follows: (1) Legislative Decree No. 1,002 – Promotion of Investment for the Generation of Electricity with the Use of Renewable Energy (2008); (2) Supreme Decree No. 012-2011-EM – Regulations for the Generation of Electricity with Renewable Energies; (3) Supreme Decree No. 020-2013-EM – Regulation for the Promotion of Electrical Investment in Off-Grid Areas; (4) Ministerial Resolution No. 203-2013-MEM/DM – Plan for Universal Access to Energy [83].
	Emissions and emissions reduction commitments	• Around 66% of CO2 emissions are produced by activities related to land use such as agriculture, forestry and direct emissions from managed soils, followed by the transport sector (which includes air, land, sea, and rail transport) with 10%, the industrial sector with 9% (including energy, manufacturing, construction, industrial processes, and product uses) and others with 15% [16]. • In 2020, Peru declared it would reduce 40% of the nation's emissions by 2030. In its NDC, the Peruvian Government commits to a maximum of 179 million tons of CO2eq emissions by 2030. It also sets the goal of reaching carbon neutrality by 2050; however, no further details have been communicated so far [242, 243, 244].
	Transport sector	• Liquid hydrocarbons are the most-consumed source in the energy sector; the transportation sector has the highest use, with 78% [16]. • The Peruvian Automotive Association, AAP, submitted a proposal to the Peruvian Government for a National Electromobility Plan to contribute to the State's efforts to promote efficient and environmentally friendly mobility [245, 246].
	Carbon pricing	• Moreover, as part of the goals contained in the NDC, Peru proposes the entry of 6,707 electric buses and 171,359 electric light vehicles by 2030 (5% of the vehicle fleet) [246]. • Peru has a Ministry of Economy and Finance (MEF) social carbon price of 7.17 USD per ton of CO2e. • Additionally, the country is preparing the infrastructure and national rules to participate in the carbon markets of the Paris Agreement [247].
	Current H2 production	• A 25 MW alkaline electrolyzer has been operating since 1965 [2].
	Current H2 use	• Oil refining, chemicals-NH3, cement [2]. H2 production is mainly used to meet the current demand for ammonium nitrate for fertilizers and explosives for the mining industry [2]. • Moreover, Peru has seven refineries with a total processing capacity of approximately 216 MBPD. In 2019, these refineries' national oil production was around 154 MBPD, representing 42 kt of demand for gray H2 [248]
H2 policy	H2 policy plan, roadmap, or strategy	• No: Strategy under development [28, 83]. Private initiatives exist [26, 50, 240]. • The Ministry of Energy and Mining has commissioned the IDB to finance a study to develop the national strategy and establish a multidisciplinary committee. • Though a public initiative has yet to be published, in 2022, the Peruvian Hydrogen Association proposed a roadmap and RH2 bill as a starting point [26, 50, 240]. The roadmap charts the development of large-scale projects by 2050, identifying main applications [86].
	Regulatory framework	• Draft bill No. 6953/2020-CR, "Law Encouraging Investment in Renewable Energy Resources for Power Generation in the Peruvian Electricity Market," Article 6.- Promotion of Green Hydrogen Production Projects, mentions that the Ministry of Energy and Mines promotes the development of RH2 projects as a mechanism to reduce transportation, industry, and agriculture emissions. This draft bill was submitted to the Congressional Energy and Mines Committee in 2021 and is currently under study [83]. • In January 2022, RH2 was introduced within the supreme decree on the climate emergency. The climate actions include designing promotion programs for technology development, use, and production of RH2, and promoting the entry of electric and RH2 vehicles [51, 249]. • The H2 regulation proposal (RH2 promotion bill), developed by H2 Peru, was distributed to the authorities for analysis and subsequent approval in the first quarter of 2022 [49, 50]. In June 2023, a favorable statement has been published by the Republic's Congress, which is a step towards the approval of the Hydrogen Promotion Law.



Peru

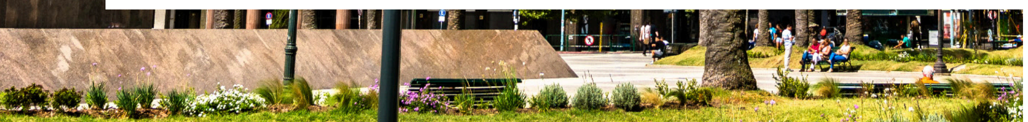
Projects	Total number	• 5 RH2 projects.
	Financing and investment	• 20 MUSD financing in 2030 would leverage scalable and replicable projects [86].
	Collaboration	• National alliance: Peruvian Hydrogen Association [250]. • In March 2023, Alta Ley Corporation and SAMMI presented the First Binational Green Hydrogen Roadmap for Mining in Chile and Peru [95].
H2 potential	H2 production	• The country has vast experience with alkaline electrolyzers [2]. • Thanks to their renewable resources, the northern and southern regions are the main potential production centers [106]. Three potential hydrogen hubs would be promoted: Ica (south), north coast (wind potential of 5 kWh/m2), and a southern coast solar potential of 5 kWh/m2. The electrolysis capacity will grow from 1 GW in 2030 to 12 GW in 2050 [86].
	H2 application and demand	• According to H2 Peru's roadmap, the main applications would be refineries, fertilizer production, NH3 production, transportation (heavy cargo such as rail transport), synthetic fuels, forklift conversion, cement, mining, and steel. This document also proposes incorporating fuel cell vehicles into the National Electromobility Plan [86]. • Central and Southern regions are the main potential consumption centers due to their energy footprints and activity [106]. The highest demand comes from the industry (center region) and mining (northern and southern regions). In the south, authorities are considering building a 1,000 km mineral railroad, which would be the first large-scale transportation project that could use RH2 [240]. • The potential national demand for RH2 could be 31.3 kt/RH2 by 2030, 100.3 kt RH2 by 2040, and 354.7 kt RH2 by 2050 [86].
	Human capital	• The required human capital skills to develop technological solutions exist, considering the experience of Industrias Cachimayo, which has operated an electrolyzer since 1965. • At least 22,000; 87,000; and 94,000 jobs could be created by 2030, 2040, and 2050, respectively [86].
	LCOH (2030)	• 2.6 USD/kg RH2 [106]
	LCOH (2040)	• 1.9 USD/kg RH2 [106]
	LCOH (2050)	• 1.0 [86]-1.3 USD/kg RH2 [106]



Uruguay

Current context	Renewable energy availability, installations, and regulation	• Electricity production from combined wind and photovoltaic solar energy could achieve low costs, with capacity factors of close to 60%. The country can generate over 2,200 TWh (more than 200 times its current electricity demand) using just 5% of the land area and 27% of the maritime area [53]. • 20 GW of renewable energies will be required to meet RH2 production goals [7]. • According to the National Energy Balance, Uruguay achieved a primary matrix with 63% RE in 2019 [251], though historically the electricity matrix had an average of 97% renewables (53% wind, solar, and biomass, and 44% hydroelectric) in 2017-2020 [7]. • Various decrees and resolutions have led to the current RE share in the electricity matrix [53, 252, 253, 254, 255, 256].
	Emissions and emissions reduction commitments	• Emissions from the transport sector are higher than those of the industrial sector [2]. • In the first NDC report of 2017, the country committed to a 24% reduction in CO2 emissions intensity per unit of GDP by 2025 compared to 1990 [257]. The second version announced a significant increase in ambition, confirming the path toward emissions stability and carbon neutrality that the country has charted in its long-term climate strategy. It also commits to incorporating 600 H2 fuel cell-powered freight vehicles into the vehicle fleet by 2030 [258]. • The Uruguayan Green Hydrogen Roadmap also states that 0.6 Mt CO2 and 7 Mt CO2 emissions will be avoided with RH2 by 2030 and 2040, respectively [7].
	Transport sector	• The transport sector consumes 77% of oil and oil derivatives in the total energy mix [251]. Road freight transport accounts for >90% of domestic freight transport [2].
	Carbon pricing	• A carbon tax was established in 2022 by converting the excise tax regime on gasoline, with a tax rate set at 137 USD per ton of CO2 emitted from gasoline combustion [259]. However, Decree 435/022 set the new value of the Uruguayan carbon tax at 6,024 UYU (USD 155.86)/tCO2e for 2023 [114].
	Current H2 use	• Cement [2].
H2 policy	H2 policy plan, roadmap, or strategy	•Yes: Roadmap published (2022) [7, 260]. • In 2018, the inter-institutional group formed by the Ministry of Industry, Energy and Mining (MIEM), the National Fuels, Alcohol and Portland Cement Administration (ANCAP), and the Electricity Generator and Transmission Administration (UTE) was created to promote and develop an H2 economy. Within this framework, strategies have been outlined to begin RH2 exports, production of raw materials and green chemicals, and the direct use of H2 in transport. • In 2021, Uruguay consulted with the IDB to deepen the H2 development strategy [53]. • The country is developing the H2U Program to promote its roadmap. With the coordination of multi-stakeholders (public and private sectors, academia, and civil society), the program will have the following components: (1) Innovation: Hydrogen Sector Fund tenders state-supported projects and research and innovation projects, National Council for Innovation, Science and Technology (CONICYT); (2) Investment: tax incentives, support in the management of permits and international positioning; (3) Infrastructure: Port aspects, electricity transmission networks, gas pipelines, use of railroads; (4) Regulation: quality and storage regulations, safety aspects, aspects related to the national electricity system, guidelines for land use and easements for gas pipelines and electricity transmission; (5) Offshore: competitive process for prospecting and evaluating RH2 production for possible future development; (6) Community and capacity building: design and implementation of a national communication plan for decarbonization and H2 aspects, and professional and technical training [7]. • The country established international cooperation partnerships for capacity building and international communication [7].
	H2 production goal (horizon)	• H2 production could be around 1Mt/year by 2040 [7].
	GW electrolysis goal (horizon)	• 0.1- 0.3 GW (2025); 1-2 GW (2030); 5 GW (2035); 10 GW (2040) [7].
	Regulatory framework	• The country does not currently have any initiatives to regulate H2 [53]. However, progress for implementing sector-specific regulations related to safety and technical standards and permitting process is to be expected by 2024 [7].

Uruguay



Projects and initiatives	Total number	• 6 RH2 projects.
	R&D	• The National Research and Innovation Agency (ANII) created the Green Hydrogen Sector Fund: 10 M USD will be granted through an open tender for proposals aimed at the private sector to implement the first production projects [7].
	Financing and investment	• IDB has supported feasibility studies and road-mapping processes [2]. • From 2022 to 2025, the design of an incentive structure will provide financial and coordination support for pilot projects. From 2026 the establishment of incentives focused on attracting investment, cost competitiveness, and stimulation of domestic demand is to be expected [7].
	Collaboration	•National alliance: Uruguay did not have an H2 association as of 2022. However, the Renewable Energies Association has been participating in H2 initiatives [261, 262]. • International cooperation: Uruguay and the World Bank Group agreed to promote sustainable economic development through a CPF for 2023-2027 [263]. A new Uruguay-Germany bilateral Energy Partnership was signed in 2023 [264].
H2 potential	H2 production	• The roadmap announces a production potential and goal of 1 Mt/year by 2040 [7].
	H2 application and demand	• Transport, thermal energy, industrial energy, raw materials, and stabilization of highly renewable electricity grids are potential demand sectors. • In particular, the deployment of trucks in the domestic market represents 0.2 Mt RH2/year demand by 2040. Maritime transport could demand 0.02 Mt RH2/year by 2040. Substituting gray fertilizer imports will require 0.02 Mt RH2/year in 2035. In the case of the export market by 2040, jet fuel and RH2 exports could demand 0.2 Mt RH2/year each, while methanol and NH3 could demand 0.02 Mt RH2/year each. Lastly, the production of DRI could require 0.5 Mt RH2/year in 2035 [7].
	Infrastructure, transport, and storage	• Uruguay contemplates infrastructure development in three phases in its roadmap. Phase 1: Planning and development of detailed engineering for pipelines, transmission lines, and ports. Development of a port solution for synfuels export in Montevideo; Phase 2: Planning and development of detailed engineering for Atlantic export ports and the implementation of infrastructure plan (i.e., pipelines and transmission lines) and coordination for deployment to capture synergies; Phase 3: Development of logistics solution for export in the coastal zone and coordination of infrastructure deployment [7].
	H2 export and trade	• A target market share of 3.5% by 2040 is proposed. That is, Uruguay would have an export opportunity of 95 million USD by 2030 and approximately 1.3 BUSD by 2040. Thus, the following market will be captured by 2040: H2 exports (0.3 MUSD), NH3 exports (0.04 MUSD), and aviation and shipping exports (0.9 MUSD) [7].
	Human capital	• 6,000 jobs will be created by 2030. By 2040, over 35,000 direct skilled jobs in plant construction, operation, maintenance, logistics, and technical education are expected [7].
	CCUS potential	• 1.5-2.4 USD/kg RH2 [7]
	Human capital	• 1.2-1.9 USD/kg RH2 [7]
	LCOH (2020)	• 1.1-1.7 USD/kg RH2 [7]
	LCOH (2030)	• 1.0-1.4 USD/kg RH2 [7]

5. Conclusions

Latin America and the Caribbean has abundant renewable resources and a strategic geographical location that will favor the production of competitive renewable hydrogen and access to international markets [1, 2]. Both governments and businesses have begun to recognize the role of renewable hydrogen in decarbonizing economies and achieving emissions reduction commitments, as well as the opportunity to improve the national gross domestic product and promote job creation. Countries such as Brazil, Chile, and Colombia are leading the region's potential to produce and export renewable hydrogen, while others like Uruguay aim to stimulate the industry's growth. Besides traditional hydrogen uses in refining or ammonia production, hydrogen-powered fuel cell vehicles are potential new applications to decarbonize the transport sector, especially for long distances or heavy-duty transportation.

In addition to the publication and announcement of public policies, the private sector has been a key player in promoting the region by developing hydrogen projects [28]. Some are operational, but most are under development in the pre-feasibility and feasibility stages. These projects are mainly concentrated in South America, while Central American countries have begun to design roadmaps and studies, accompanied by few pilot projects.

However, more national efforts are needed to convert the hydrogen potential into production. According to the International Energy Agency, the following actions are required to achieve scale-up,: (1) establish long-term goals or policies to secure hydrogen's role for investors, (2) stimulate commercial demand for clean hydrogen, (3) address the investment risks of first-movers, (4) support R&D demonstration projects and exchange of knowledge, and (5) harmonize standards and eliminate regulatory barriers [3, 265].

Considering the region's current context and expectations that several countries will have a published or ongoing national strategies this year [113], most of the projects have difficulties achieving a final investment decision (FID). The estimation and stimulation of hydrogen demand and the need to de-risk hydrogen projects remain highly relevant for projects to make progress toward an FID. Finding and securing offtake agreements demonstrates long-term bankability and return on investment. However, doing so is challenging as there is a significant gap between the price expectations of hydrogen buyers and sellers. Thus, it is expected that government intervention and subsidies will play a key role to make offtake contract negotiations more attractive. This has been the case in the European Union, under RePowerEU, and in the United States under the Infrastructure, Investment and Jobs Act and the Inflation Reduction Act. The design of competitive financial instruments in other regions and the lack of attractive incentives within the region are provoking redistribution of investment. Multilateral development banks are well-positioned to help the renewable hydrogen industry in emerging and developing economies, due to climate finance commitments, risk reduction capacity, and knowledge and expertise. Moreover, significant supply-side risk exists. Though it will improve over time, early moving offtakers can face risks to the secure supply of renewable hydrogen and hydrogen-derived products. By co-locating supply and demand in industrial clusters, hydrogen can be obtained from multiple sources and suppliers can have several potential offtakers.

Lastly, the international hydrogen trade that will be enabled in the coming years will require establishing certification systems to guarantee the credibility and transparency of products' attributes, such as distinguishing the different forms of hydrogen, their life-cycle carbon footprints, and additional sustainability criteria. However, this need also applies to the different low-carbon hydrogen production methods hydrogen uses in LAC to decarbonize the countries' own economy. Establishing a harmonized regional certification scheme to avoid duplication of efforts and operation of multiple standards that might hamper regional trade would be a step in the right direction.

Latin America and Caribbean countries must make strategic decisions, considering long-term goals and benefits and public-private cooperation. For their part, multilateral development banks are well-positioned to help the renewable hydrogen industry in emerging and developing economies due to climate finance commitments, risk reduction capacity, and knowledge and expertise. With their support, large-scale private investment could be mobilized in the region and Latin America and the Caribbean could maintain its position within the global hydrogen economy [266].

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7. Appendix: Nomenclature

Abbreviation	Meaning
AAP	**Peruvian Automotive Association**
AFOLU	**Agriculture, Forestry, and Land Use Change**
ANCAP	**National Fuels, Alcohol and Portland Cement Administration (Uruguay)**
ANDI	**National Business Association (Colombia)**
ANEEL	**Electricity Regulatory Agency (Brazil)**
ANII	**National Research and Innovation Agency (Uruguay)**
ANID	**National Research and Development Agency (Chile)**
ASDIT	**Association for the Development of the Technological Institute**
BCLP	**Billion Chilean Peso**
BEN	**National Energy Balance (Brazil)**
BEV	**Battery Electric Vehicle**
BMU	**Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Germany)**
BRICS	**Energy Research Cooperation Platform**
BNDES	**Brazilian National Development Bank**
BUSD	**Billion US Dollar**
CAEX	**High tonnage mining trucks**
CCS	**Carbon capture and storage**
CCUS	**Carbon capture, utilization, and storage**
CH4	**Methane**
CEL	**Clean Energy Certificate**
CENEH	**National Reference Center for Hydrogen Energy (Brazil)**
CFE	**Federal Electricity Commission (Mexico)**
ChileValora	**Chile's National Labor Competency Certification System Commission**
CIF	**Climate Investment Fund**
CIP	**Copenhagen Infrastructure Partners**
CLP	**Chilean Peso**
CNG	**Compressed natural gas**
CNPE	**National Council for Energy Policy (Brazil)**
CO2	**Carbon dioxide**
CO2eq	**CO2 equivalent**
CO2e	**CO2 equivalent**
Codelco	**Chile's National Copper Corporation**
CONICYT	**National Council for Innovation, Science and Technology (Uruguay)**
CONPES	**National Council for Economic and Social Planning (Colombia)**
COP	**Conference of the Parties**
CORFO	**Chile's Economic Development Agency**
CPF	**Country Partnership Framework**
CRE	**Energy Regulation Committee (Mexico)**
CRUSA	**Costa Rica-United States Foundation for Cooperation**
DC	**Direct current**
DDU	**Urban Development Division (Chile)"**
DIPRES	**Budget Office (Chile)**

Abbreviation	Meaning
DME	**Dimethyl ether**
DRI	**Direct reduced iron**
ECLAC	**Economic Commission for Latin America and the Caribbean**
ECOPETROL	**Colombian Petroleum Corporation**
ECR	**Effective Carbon Rate**
EJ	**Exajoule**
EMTU	**Empresa Metropolitana de Transporte Urbano (Brazil)**
ENAP	**National Petroleum Company (Chile)**
EOR	**Enhanced oil recovery**
EPE	**Energy Research Office (Brazil)**
EPM	**Empresa de Servicios Públicos de Medellín (Colombia)**
ETS	**Emissions trading system**
EU	**European Union**
EUR	**Euro**
FC	**Fuel cell**
FCEV	**Fuel cell electric vehicle**
FENOGE	**Fund for Non-Conventional Energies and Efficient Energy Management (Colombia)**
FID	**Final investment decision**
FNCE	**Unconventional Energy Sources**
FNCER	**Unconventional Renewable Energy Sources**
FONHIDROV	**National Green Hydrogen Development Fund (Argentina)**
FPTI	**Itaipu Technology Park Foundation**
GDP	**Gross domestic product**
GHG	**Greenhouse gas**
GHI	**Global horizontal irradiance**
GIZ	**German International Cooperation Agency**
Gpc	**Giga cubic feet**
GW	**Gigawatt**
GWh	**Gigawatt hour**
h	**Hour**
H2	**Hydrogen**
ha	**Hectare**
HBI	**Hot briquetted iron**
HPP	**Hydroelectric Power Plant**
hr	**Hour**
ICE	**Institute of Electricity (Costa Rica)**
IDB	**Inter-American Development Bank**
IDB Lab	**Innovation Lab of the Interamerican Development Bank**
IEA	**International Energy Agency**
IEASA	**Today's Energía Argentina Sociedad Anónima, State owned company in Argentina**
INEEL	**National Institute of Electricity and Clean Energy (Mexico)**
INEGYCEI	**National Inventory of Greenhouse Gas and Compound Emissions (Mexico)**
INERE	**National Renewable Energy Inventory**
IRENA	**International Renewable Energy Agency**
ISF	**Institute for Sustainable Futures**

Abbreviation	Meaning
ISO	**International Organization for Standardization**
ITL	**Chilean Institute of Clean Technologies**
KFW	**German state-owned investment and development bank**
kg	**Kilogram**
kt	**Kilotonnes**
kW	**Kilowatt**
kWh	**Kilowatt hour**
L	**Liter**
LAC	**Latin America and the Caribbean**
LATAM	**Latin America**
LCOH	**Levelized cost of hydrogen**
LDV	**Light-duty vehicles**
Li	**Lithium**
LNG	**Liquefied natural gas**
LPG	**Liquefied petroleum gas**
LULUCF	**Land use, land-use change, and forestry**
m	**Meter**
MBPD	**Thousand barrels per day**
MCLP	**Million Chilean Pesos**
MEF	**Ministry of Economy and Finance (Peru)**
MER	**Central America's regional electricity market**
MIEM	**Ministry of Industry, Energy and Mining (Uruguay)**
MINAE	**Ministry of Environment and Energy (Costa Rica)**
MME	**Ministry of Mines and Energy (Brazil)**
MoU	**Memorandum of understanding**
MPa	**Megapascales**
Mt	**Megatonnes**
Mtoe	**Million tonne of oil equivalent**
MUSD	**Million US dollar**
MW	**Megawatts**
MWh	**Megawatts hour**
MXN	**Mexican peso**
N2O	**Nitrous oxide**
NAMA	**Nationally Appropriate Mitigation Action**
NCRE	**Non-conventional renewable energies**
NDC	**Nationally determined contribution**
NH3	**Ammonia**
NFPA2	**National Fire Protection Association 2, Hydrogen Technologies Code**
NG	**Natural gas**
Nm3	**Normal cubic meter**
NREL	**National Renewable Energy Laboratory**
O2	**Oxygen**
OLADE	**Latin American Energy Organization**
OSINERGMIN	**Supervisory Agency for Investment in Energy and Mines (Perú)**
PDEE	**Energy Expansion Plan (Brazil)**
PEM	**Polymer electrolyte membrane**
PEMEX	**Mexican state-owned petroleum company**
PEN	**National Energy Plan (Colombia)**
PM	**Particulate matter**
PNH2	**National Hydrogen Program (Brazil)**
PNE	**National Energy Plan (Brazil)**
PPA	**Power purchase agreement**
PRONASE	**National Program for Sustainable Energy Use (Mexico)**
PV	**Photovoltaic**
R&D	**Research and development**
R&D&i	**Research and development and innovation**
RE	**Renewable energy**
RECOPE	**Costa Rican Oil Refinery**
RED	**Metropolitan Mobility Network (Chile)**
REI	**Renewable Energy Integration**
RFI	**Request for information**
RH2	**Renewable hydrogen**
s	**Second**
SAF	**Sustainable aviation fuel**
SAMMI	**SAMMI Andean Mining Cluster (Perú)**
SDG	**Sustainable Development Goal**
SEC	**Superintendency of Electricity and Fuels**
SEIA	**Environmental Impact Assessment System (Chile)**
SEMARNAT	**Secretariat of Environment and Natural Resources (Mexico)**
SEN	**National Electric System (Chile)**
SENA	**National Learning Service (Colombia)**
SENAI	**National Service of Industrial Training (Brazil)**
SÉNECA	**Energy Sustainability Alliance for Colombia (Colombia)**
Sep	**September**
SEPSE	**Energy Subsector Planning Secretariat (Costa Rica)**
SICA	**Central American Integration System**
t	**Tonne**
ton	**Tonne**
TWh	**Terawatt-hour**
UACH	**Austral University of Chile**
UK	**United Kingdom**
UN	**United Nations**
UNFCCC	**United Nations Framework Convention on Climate Change**
UPME	**Energy Mining Planning Unit (Colombia)**
US	**United States**
USAID	**United States Agency for International Development**
USD	**US Dollar**
UTE	**National Administration of Power Plants and Electrical Transmissions (Uruguay)**
UTFSM	**Universidad Técnica Federico Santa María (Chile)**
UYU	**Uruguayan peso**
VAT	**Value-added tax**
YPF	**Yacimientos Petrolíferos Fiscales (Fiscal Oilfields, Argentina)**
Y-TEC	**YPF Tecnología S.A**

8. Appendix: LAC renewable hydrogen projects

The following Appendix details existing hydrogen projects in Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay that are either in operation or under development. This section considers both pilot and industrial-scale projects.

Argentina

In operation

Pico Truncado [2, 267, 268, 269]

- By the municipality of Pico Truncado and the Government of Santa Cruz.
- Experimental scale RH2 project; preparing to advance to a semi-industrial scale (announced in 2021).
- In operation since 2005. The plant was shut down for 5 years but has since resumed operation.
- Located in the municipality of Pico Truncado.
- First experimental LATAM H2 plant.
- It has three alkaline electrolyzers. However, one with a capacity of 500 kW would allow semi-industrial production of 100 Nm3 of H2 per hour and 50 Nm3 of O2 per hour. The plant is supplied with renewable electricity generated by the Jorge Romanutti wind farm.
- H2 would be used for a gas blend (30% volume with CNG) for transport, while O2 would be used for hospital requirements.

Hychico [2, 28, 38, 270, 271]

- By the companies Hychico and Hydrogenics.
- RH2 project at the pilot scale.
- In operation since 2008.
- Located 20 km from the city of Comodoro Rivadavia, in Chubut Province (Argentine Patagonia).
- First LATAM pilot H2 project.
- It has two alkaline water electrolyzers with a total capacity of 0.55 MW, supplied with wind power of the Diadema Wind Farm, which has a total installed capacity of 6.3 MW, and produces 120 Nm3/h H2 (52 t H2/year) and 60 Nm3/h O2. A second wind farm with a total installed capacity of 27.6 MW has also begun to supply renewable energy.
- H2 produced is for own consumption. The H2 is blended with NG to feed a 1.4 MW genset equipped with an internal combustion engine that can operate over a wide range of gas/H2 blends, including pure H2. The high-purity O2 produced is sold at high pressure in the industrial gas market.
- In 2015, the project built a 2.3 km-long polymeric pipeline to transport H2 from its electrolysis plant to the underground storage project, which is currently under development.
- the project has been testing the capacity of a depleted oil well as reservoir. In 2016, Hychico started a pilot project to produce methane from hydrogen and carbon dioxide through underground controlled methanogenesis.

Under development

El Alamito [28, 272, 273, 274]

- RH2 project on a pilot scale.
- Solar Park under construction since December 2021. Beginning of operation is expected for 2023.
- Located at Neuquén.
- It has a 1 MW solar park, which could scale up to 6 MW. It will have an H2 generator by air dehumidification.

Proyecto Pampas [272, 275, 276, 277]

- By Fortescue Future Industries.
- Industrial scale RH2 project.
- Located in Río Negro Province.
- With an investment of 8.4 BUSD, the project foresees the construction of 2,000 MW in wind power. It is currently completing prefeasibility studies, including socio-environmental assessments. The pilot stage would produce 35 kt RH2 by 2024 and would scale to an annual production capacity of 2.2 Mt RH2 for export.

BUQUEBUS H2 Ferry [28, 278, 279]

- By Buquebus and TCI Gecomp.
- Demand-side RH2 project.
- The project involves feasibility studies, as well as H2 as a fuel for a fleet of ferries operating between Argentina and Uruguay before 2025.

HYCHICO Pilot Project for export [28, 271]

- By Hychico.
- RH2 pilot project.
- H2 for export is considered. The project is still being defined.

HYCHICO FC Bus Project [28, 271]

- By Hychico.
- RH2 demand-side project.
- The project involves 10 FC buses.

Argentina

Under development

Río Diamante Solar [28]

MoU IEASA and Fraunhofer Institute [28, 272, 280]

- By IEASA and Fraunhofer Institute.
- RH2 project at large-scale.
- Located on 200 ha in Bahía Blanca, Buenos Aires Province.
- Uses offshore wind generation for hydrogen production.
- H2 for local use and export.

Y-TEC H2 bus [281]

- By Y-Tec and the La Rioja Secretary of Transport and Mobility of.
- Demand-side RH2 project.
- Expected to be completed by 2023.

MMex Austral H2 [282]

- By MMex Resources and Siemens Energy.
- Large-scale RH2 project.
- In Río Grande, Tierra del Fuego Province.
- Investment of 500 MUSD, including the construction of a wind farm to supply an electrolysis plant to produce 55 tons of RH2 per day (160 MW power output), as well as ammonia. The technical pre-feasibility studies and the engineering for the electrolysis plant has been completed.
- H2 and NH3 would be exported.

Brazil

In operation

Hybrid FC bus [28, 93, 97]

- By Empresa Metropolitana de Transporte Urbano de São Paulo (EMTU/SP) and the Ministry of Mines and Energy (MME).
- Demand-side project.
- 1 unit. Project stages were as follows: phase 1-feasibility (2006-2013); phase 2-efficiency improvement and implementation (2012–2016).
- For urban transport.

Refueling station [93, 97]

- 1 unit.
- 35 MPa on-site production.

FURNAS/Base Energia Sustentável [28]

- H2 use for electricity generation.

CESP/Base Energia Sustentável [28]

- Operational between 2010 and 2012.
- H2 use for gas injection and electricity generation.

Itaipu HPP complex [28, 102]

- By Itaipu Binacional, Eletrobras and Fundação Parque Tecnológico Itaipu (FPTI), with the support from Unicamp's National Reference Center for Hydrogen Energy (CENEH).
- RH2 pilot project.
- Experimental H2 plant in operation since 2014.
- Located at Itaipu Binacional HPP.
- RH2 production via alkaline electrolysis.
- H2 is used for a 6-kW fuel cell to power a 1.4 MW lighting system. The project's main objective is to use the power that is no longer generated by the reservoir's surplus water to supply a large H2 production plant.

São Gonzalo do Amarante [28, 280, 284, 285]

- By EDP Brazil.
- Pilot scale RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- 7.5 MUSD investment. A 3 MW solar PV farm will supply the RH2 plant, which would use a PEM electrolyzer.
- H2 use for industrial feedstock.

Under development

Storage plant [93, 97]

- H2-based energy storage plant built to store 200 MWh/year.

Storage plant [93, 97]

- H2-based energy storage plant built to store 730 MWh/year.

H2 fuel cell catamaran [93, 97]

- Capacity for 100 passengers.

CEMIG [28]

Vale Powership [28]

COPPE UFRJ – Hybrid Fuel Cell bus [28]

COPPE UFRJ – PACOS – BNDES [28]

Hub Pécem-Ceará [28, 93, 97]

- RH2 hub.
- Operation is expected to beg8in in 2025.
- It will have an electrolysis capacity of 5 GW. RH2 production will be 900 kt/year, occupying 200 ha.

Port of Pecem Fortescue Future [28, 283, 285]

- By Fortescue Future Industries.
- Industrial-scale Industrial scale RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- 6 BUSD investment. RH2 production of 15 Mt H2/year. Expected to begin operation in 2025.

Brazil

Under development

- H2 for export.

Marítimo Dragão [28, 283, 286]
- By Qair Brazil.
- Industrial scale RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- 6.95 BUSD investment. Offshore wind and RH2 plant. H2 production of 296 kt/year. Expected to begin operation in 2023.
- H2 for export.

Enegix Energy [28, 283, 287]
- By Enegix Energy Pte Ltd.
- Industrial scale RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- 5.4 BUSD investment. 3.4 GW of combined baseload solar and wind power will supply the electrolysis plant to produce 600 kt of RH2/year.
- H2 for export.

Engie [28, 283]
- By Engie.
- Located in the Port of Pecém, Ceará (hub).
- Memorandum signed.
- H2 for export, but also assessing use in several areas (steel production, industrial feedstock, blending, transport).

Transhydrogen Alliance [28, 283]
- RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- 2 BUSD investment. Production of 500 kt of RH2/year.
- H2 for industrial feedstock.

Linde [28, 283]
- By Linde.
- RH2 project.
- Located in the Port of Pecém, Ceará (hub).
- Memorandum signed for RH2 plant.

White Martins [28, 283]
- Located in the Port of Pecém, Ceará (hub).
- Memorandum signed.

Neoenergía/Iberdrola [283]
- Located in the Port of Pecém, Ceará (hub).
- Memorandum to analyze the use of RH2 in public transport.

H2helium [283]
- Located in the Port of Pecém, Ceará (hub).
- Memorandum signed to act in project development.

Eneva, Differential, Hytron [283]
- Located in the Port of Pecém, Ceará (hub).
- Memorandum signed.

AES Brasil [28]
- By AES Brasil.
- Located in the Port of Pecém, Ceará (hub).
- H2 for export.

Ingenostrum – Total Eren [28, 288, 289]
- By Total Eren and Ingenostrum.
- Located in the Port of Pecém, Ceará (hub).

Brazil

Under development

- 1.4 BUSD investment for the construction of a 2 GW PV plant and a RH2 production plant.
- H2 use for electricity generation.

Cactus Energia Verde Port of Pecem [280, 290]

- By Cactus Energia.
- Located in the Port of Pecém, Ceará (hub).
- 10.5 kt H2/month. Expected to begin operations in 2026.

Enerprize Energy [28, 283]

- Located in Rio Grande do Norte (hub).
- Memorandum signed for offshore wind and an RH2 plant with ammonia production.
- Products for export.

International Renewable Energies [283]

- Located in Rio Grande do Norte (hub).
- Investment of 3.2 BUSD in offshore wind, solar and RH2 plant.

Neoenergía/Iberdrola [283]

- Located in Rio Grande do Norte (hub).
- Memorandum with intention to produce RH2.

Pernambuco Green Hydrogen Plant [283]

- By Qair Brazil.
- Located in the Port of Suape, Pernambuco.
- Investment of 3.8 BUSD in H2 plant.

Neoenergía/Iberdrola [283]

- Pilot scale RH2 project.
- Located in the Port of Suape, Pernambuco.
- Memorandum signed. Port of Acu, Rio de Janeiro.

Porto do Acu Fortescue Ammonia Project [102, 280, 283]

- By Fortescue Future Industries.
- RH2 project.
- Located in Port of Acu, Rio de Janeiro.
- Production of 250 kt of ammonia/year, with a 300 MW capacity.
- Ammonia use for fertilizer industry and export.

White Martins [280]

- Located in Rio Grande do Sul.
- Memorandum signed.

Unigel [28, 98, 280, 291, 292]

- By Unigel.
- Industrial scale RH2 plant.
- Located in the Camaçari industrial complex in the state of Bahia.
- 120 MUSD investment for an onshore wind farm and a RH2 plant that uses alkaline electrolysis. Phase I considers a 60 MW total electrolysis capacity to produce 10 kt RH2/year for a 60 kt ammonia production, which is expected to begin operation by the end of 2023. Phase II will consider a 240 MW electrolysis capacity and is expected to begin in 2025.

Raízen and Yara Biomethane to H2 for fertilizer [28]

Nexway and Casa Dos Ventos in Piauí [28]

Shell Acu Port [280, 293]

- By Shell.
- Pilot scale RH2 project.
- Located in Port of Acu, Rio de Janeiro.
- Grid electricity will supply the RH2 plant. Initial capacity of 10 MW to produce 2 kt H2/year, with a potential scale-up to 100 MW to produce 16 kt H2/year. Expected to be completed in 2025.

Brazil

Under development

Ethanol-based H2 plant and fuelling station [294]

- By Shell Brazil, Raízen, Hytron, the University of São Paulo, and SENAI CETIQT.
- Located in São Paulo.
- MoU for the construction of a H2 production plant using ethanol. It consists of two phases: the first plant will have an output of 5 kg/h of RH2, while the second plant will have an output of 44.5 kg/h of RH2. Expected to start operations in 2023.

BBF Project for SAF [28, 295, 296]

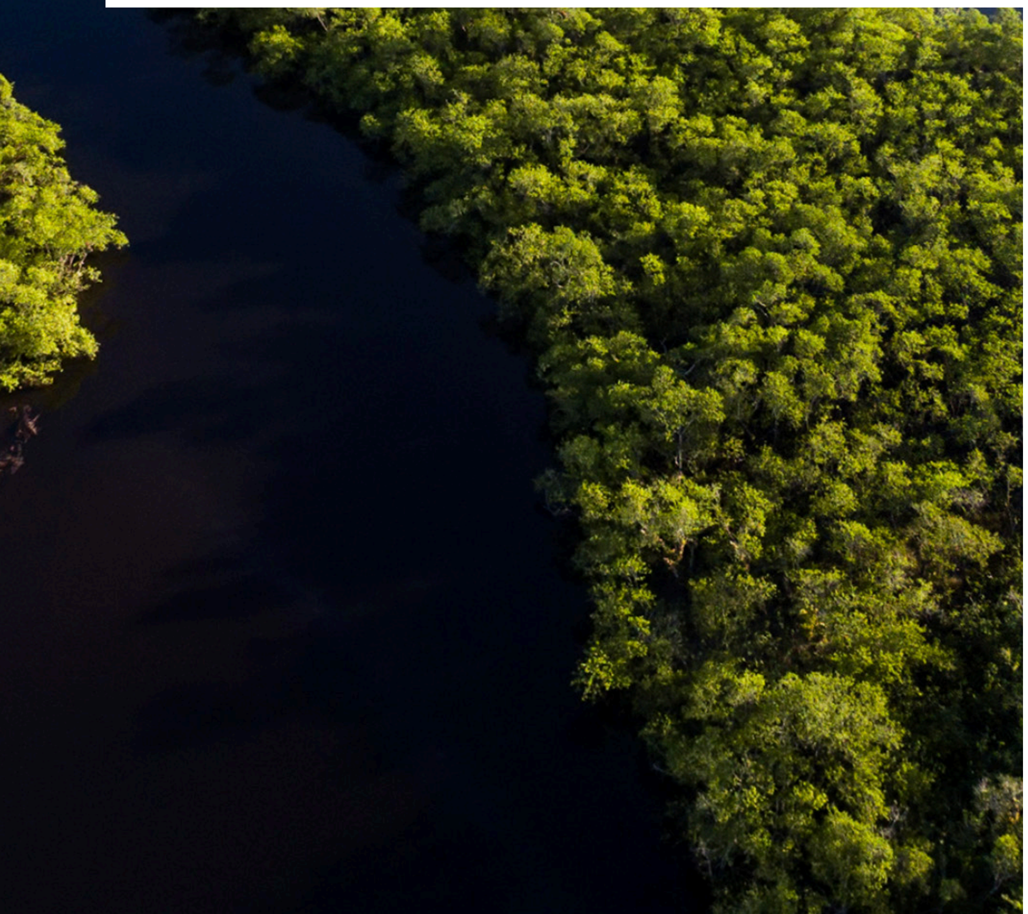
- By Brasil BioFuels.
- Located in Manaus.
- Biorefinery for sustainable aviation fuel and second-generation biofuel. Production capacity of 500 kt/year. Operation expected to start in 2025. Vibra Energy as partner through a five-year contract to sell the SAF.

UNIFEI [297]

- Investigation center financed by GIZ. 1MW. Minas Gerais. R&D, incubation and startups.

Enerfin [298]

- RH2 project.
- Located in Rio Grande do Sul.



Chile

In operation

Cerro Pabellón microgrid [2, 56]

- By Enel Green Power Chile Ltda and ENAP.
- Pilot scale RH2 project.
- Located in the Antofagasta Region.
- Operational since 2017.
- Uses solar power to produce 10 tons of H_2/year using a 50 kW PEM electrolyzer. It provides dispatchable renewable electricity to cover the needs of a microgrid serving a community of over 600 technicians working at a geothermal plant.

Anglo American Hydrogenerator [62, 71]

- By Anglo American.
- Pilot scale RH2 project.
- Located in the Metropolitan Region.
- In operation since 2021
- First Chilean hydrogenerator for zero carbon vehicles, at Planta Las Tórtolas. Renewable electricity comes from 2 solar plants (86 kW and 100 kW). Water from the mining process is reused in an electrolyzer, which has a production capacity of 2 kg H_2/day.
- Gaseous H_2 is dispensed to a forklift that is powered by clean energy generated with a fuel cell. The project also incorporates a stationary fuel cell, which re-injects energy into the operation's electricity grid.

Haru Oni [2, 62, 66, 67].

- By HIF, Enel Green Power, Siemens, Gasco, ENAP, Porsche, and Exxon Mobile.
- Pilot scale RH2 project.
- Located in the Magallanes Region.
- In operation since 2022.
- Operates with a 3.4 MW wind turbine to supply renewable electricity to produce synthetic fuel (e-gasoline) from methanol. The electrolyzer capacity is 1.2 MW, and e-fuel production is 130,000 L/year. Includes a scale-up project (HIF project) to target export markets beyond the region. Construction started in Sep 2021 it had 1.25 MW electrolysis capacity.
- In March 2023, it announced the shipment of the first 2,600 liters of e-Fuels to the United Kingdom.

H2GN [62, 69, 70, 299]

- By Gas Valpo. University of La Serena will monitor the project.
- Pilot scale RH2 project.
- Located in the Coquimbo Region.
- In operation since 2022.
- Through a PPA and 9 kW of photovoltaic power supply system installed on the same side, renewable electricity is supplied to 150 kW nominal electrolysis power with a production capacity of 65 kg/day.
- RH2 production for blending in NG pipelines (up to 20% H_2) involving over 1,800 homes in Coquimbo and La Serena.

Mobile green hydrogen plant [68, 300]

- By Cicitem.
- Pilot scale RH2 project.
- Located in the Antofagasta Region.
- In operation since 2022
- It uses 33 kW photovoltaic panels to supply 8 electrolyzers-2.5 kW each-reaching a total electrolysis capacity of 20 kW. The project seeks to quantify the real potential of the Antofagasta Region to produce H_2; it measures the efficiency of H_2 production under different conditions such as altitude, humidity, solar radiation, as well as H_2 consumption in photovoltaic and fuel cells.

Chile

Under development

Forklifts [62, 196, 301, 302]

- By Engie, Walmart, and Plug Power.
- Pilot scale RH2 project.
- Located in the Metropolitan Region.
- A solar PV facility would generate 3 GWh/year to supply the of 0.6 MW electrolyzer with power to produce 10.8 kg RH2/hr. Investment of 15 MUSD. Expected to complete construction in 2023.
- Use of RH2 in transport. The project includes replacement of lead-acid batteries in 259 forklifts with RH2 fuel cells.

Minera San Pedro/CNP Project [62, 303]

- By Minera San Pedro, Centro Nacional de Pilotaje, Busso Group, and Centro Energía UC.
- Pilot scale RH2 project.
- Located in the Metropolitan Region.
- Use of RH2 (initially 3.46 ton/year) in backup power generation equipment to supply the plant's communication system and a forklift for warehouse management. Currently under construction, it is expected to enter operation during 2023.

UCSC [62, 304]

- By UCSC, with public funding.
- Located in the Biobío Region, at the University.
- RH2 plant for applied research in H2 production and use in electric vehicles.
- Production of 0.8 ton/year of RH2 through a 25 kW electrolyzer. The project is currently under construction.

HyEx [2, 62, 305]

- By Engie and Enaex.
- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- It uses solar power and renewable electricity from the grid to produce ammonia and includes a pilot and scale-up phase. The pilot phase considers 26 MW of nominal electrolysis power to produce 18,000 ton/year of ammonia, while the industrial scale one will have 2,000 MW of electrolysis to produce 700,000 ton/year of ammonia. The demineralized water supply will come from the Tocopilla Thermoelectric Power Plant. The project also considers a H2 compression and storage system, which will allow H2 to be supplied throughout the day, without electrolysis operation necessarily being con-tinuous. The pilot phase has environmental permitting through impact assessment statements for both the hydrogen and ammonia pilot plants. CORFO contribution of 9.53 MUSD
- Aims to replace imported ammonia by using RH2 to produce ammonia and ammonium nitrate for its application in the mining sector. Industrial scale targets export markets beyond the region.

H2 Magallanes [306, 307, 308]

- By Total Eren, with ENAP collaboration.
- Industrial scale RH2 project.
- Located in San Gregorio, Magallanes Region.
- Plant with 10 GW of installed wind capacity and 8 GW electrolysis capacity, in addition to a new port terminal. Its projected production capacity is of 800,000 tons of RH2/year, and 4.4 Mt NH3/year. Considers the use of a desalination plant.
- RH2 will be used to produce ammonia for export.

Power to Ammonia [309]

- By AES Andes.
- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- 800 MW renewable power supply will allow a production of 50,000 tons H2/year and 250,000 tons ammonia/year. Desalinated water will be used. Beginning of operation is expected for 2025.
- Renewable ammonia for export and use as fuel in maritime transport.

Antofagasta Mining Energy Renewable (AMER) [62, 310]

- By Air Liquide.
- Industrial scale RH2 project.
- Electrolyzer with 80 MW nominal capacity to produce 60,000 tons of e-methanol/year. CORFO contribution of 11.79 MUSD

San Pedro de Atacama Project [62]

- By Cummins Chile and CESPA
- Located in the Antofagasta Region.
- 4 MW in solar power will supply an electrolyzer with 2.2 MW nominal capacity to produce 143 tons of RH2/year. Includes RH2 storage.

Chile

Under development

- Equipped with a fuel cell system to supply electricity in isolated zones.

Green Steel Project – H2V CAP [62, 311, 312]

- By Siderúrgica Huachipato (CAP) and Paul Wurth
- Located in the Biobío Region.
- With a nominal electrolysis capacity of 12 MW, 1,550 tons of RH2/year will be produced. CORFO contribution of 3.63 MUSD.
- RH2 for iron industry-green steel. Partial (followed by total total) replacement of coke (fuel) in steel production and to decarbonize the trucks and railways used in the transport of steel.

Faraday [62, 313]

- By Aker Clean Hydrogen and Mainstream Renewable Power.
- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- 3,500 MW in wind and solar power will supply the electrolysis process, with a nominal capacity of 2,000 MW to produce 250,000 tons of RH2/year and 1.3 Mt NH3/year. The project considers a desalina-tion plant and is expected to begin operation in 2027.
- RH2 production for ammonia synthesis, which is destined for export.

HOASIS [62, 314]

- By TCIGECOM.
- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- 4,500 MW of solar power will supply the electrolysis process with a nominal power of 2,100 MW. This will allow a production of 102,000 tons of RH2/year and 250,000 tons of NH3/year.
- RH2 for multiple uses.

HyPro Aconcagua [62, 315]

- By Linde and ITM Power. Offtake MoU with ENAP.
- Industrial scale RH2 project.
- Located in the Valparaiso Region.
- 3,600 tons of RH2/year through electrolysis with nominal power of 24 MW. CORFO contribution of 2.42 MUSD.
- Partial grey H2 replacement in oil refinery.

Quintero Bay H2 hub [62, 316]

- By GNL Quintero, Enagas, and Acciona Energía.
- Industrial scale RH2 project.
- Located in the Valparaíso Region.
- 430 tons of RH2/year through 10 MW installed electrolysis capacity. CORFO contribution of 5.73 MUSD.
- RH2 for domestic market, such as mixed with NG (blending), or as a replacement for other fuels in industrial processes, mining, and ports (coal, diesel).

HNH Energy [62, 317]

- By AustriaEnergy, Ökowind, and CIP.
- Industrial scale RH2 project.
- Located in the Magallanes region.
- It will have 1.7 GW of wind generation and an electrolysis capacity of 1,300 MW to produce 150,000 tons of RH2/year and 850,000 tons NH3/year. The project owns 22,000 hectares and will have a port terminal for export. Investment of 3 BUSD.
- Renewable ammonia for export.

Paracelus [62, 318]

- By Humboldt Hidrógeno Verde and Mejillones Port Complex.
- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- The project has an off-grid PV plant to supply the electrolysis process. Nominal electrolysis power of 10 MW (pilot project), with a further scale-up to reach 2,000 MW to produce 110,000 tons of RH2/year and 600,000 tons NH3/year (by 2027) and 550,000 tons of RH2/year (by 2035). Considers a desalination plant and a transformation and storage plant.
- RH2 for trains, mining, and possible export as ammonia or liquefied H2.

Pauna Geener Future [62, 319]

- By Starkraft.

Chile

Under development

- Industrial scale RH2 project.
- Located in the Antofagasta Region.
- RH2 and ammonia production, based on the energy supply from the Paun photovoltaic plant in Maria Elena. Supply for local market and export of ammonia.

Port of San Antonio [62, 320]

- By Solek and San Antonio Port.
- Located in the Valparaíso Region.
- Leyda PV plant will supply solar power for the electrolysis process. The first phase will involve 100 MW electrolysis capacity to produce 8,500 tons of RH2/year, while the second phase will involve a 400 MW electrolysis capacity to produce 170,000 tons of NH3/year.
- Aims to provide energy to different equipment and operations of the port, as well as possible export.

Hvallesur [62, 321]

- By TCIGECOMP.
- Pilot scale RH2 project.
- Located in the Ñuble and Biobío Regions.
- 11 MW in solar power will supply the 5 MW electrolysis process to produce 416 tons of RH2/year. Its pilot project is "Piloto 1 Hidrogenera Chillán". The entire project will be divided among three different locations: Chillán, Concepción, and Los Ángeles. An H2 refueling station with onsite production will be installed at each one.
- RH2 production for mobility application that allows the development of RH2 corridors for the heavy transport of logs by the forestry industry.

H2 Kalisaya [322]

- By Genesis Venture and INDHO.
- Located in the Biobío Region.
- RH2 plant with an electrolysis capacity of 1 MW to produce 2,000 tons of RH2/year.

El Zorzal [322]

- By Tikuna.
- Located in the Biobío Region.
- With 10.5 of installed wind and solar power generation capacity and an installed electrolysis capacity of 9 MW, 300 kg RH2/day can be produced.
- RH2 production for forestry industry.

Vientos Magallánicos [62, 323]

- By RWE Renewables.
- Industrial scale RH2 project.
- Located in the Magallanes Region.
- Through 700 MW in wind power and 835 MW in electrolysis capacity, 63,000 tons RH2/year and 350,000 tons NH3/year will be produced.
- Products are destined for export to European markets.

Genesis [62]

- By Antuko.
- Industrial scale RH2 project.
- Located in the Antofagasta region.
- Using energy from the grid or from renewable PPAs and 100 MW in electrolysis capacity, a production of 6,200 tons of RH2/year will be reached. Operation expected to begin in 2025.

Tango [62]

- By HyNewGen, Gasco, Vopak, Port of Rotterdam, and Linde.
- Industrial scale RH2 project.
- Located in the Antofagasta region.
- 600 MW installed renewable energy capacity will supply the process to produce 30,200 tons of RH2/year and 172,000 tons of NH3/year. Operation expected to begin in 2027.
- RH2 for ammonia export.

H1 Magallanes [62]

- By CWP Global.
- Industrial scale RH2 project.
- Located in the Magallanes region.
- A 2.2 GW wind farm will supply the process to produce 1 Mt NH3/year and 170 kt RH2/year. Ancillary systems will be installed for water desalination, intelligent hydrogen storage, backup power,

Under development

ammonia storage, and export facilities. The aim is to build a global-scale ammonia synthesis train that will enable economies of scale and competitive costs. Operation is expected to begin in 2028.
- Renewable ammonia for export.

Gente Grande [62]
- By TEG, Haura Energy, and Hive Energy.
- Industrial scale RH2 project.
- Located in the Magallanes region.
- 1 GW wind farm, which will be scaled up to 3 GW to produce 250 kt RH2/year and 1,250 kt NH3/year. Large-scale operation is expected for 2028.
- RH2 for ammonia export.

Cabeza del Mar [62]
- GHEnergy and Free Power.
- Industrial scale RH2 project.
- Located in the Magallanes region.
- With a 1 GW wind farm and other energy supplies, 130 kt RH2/year and 750 kt NH3/year will be produced. Operation is expected to begin in 2027.
- RH2 for ammonia export.

Pionero [62]
- By Consorcio Eólico.
- Industrial scale RH2 project.
- Located in the Magallanes region.
- Wind farm with a capacity of 2,000 MW will supply a production of 120 kt RH2/year and 700 kt NH3/year. Operation is expected to begin in 2028.
- RH2 for ammonia export.

H2 Solar Project [62]
- By Air Liquide, Atamostec, CEA, Universidad Antogasta, and CDEA.
- Located in the Antofagasta Region.
- Through 1.2 MW solar power capacity, 48 tons of RH2/year will be produced.
- Possible supply to transport commuting mining workers.

Adelaida [324]
- By AES Andes.
- Located in the Antofagasta Region.
- Solar power will supply the electrolysis process with a capacity of 2.5 MW to produce 1 ton of RH2/day

Proyecto Piloto H2V GNA [325]
- By GNA, Espinos S.A, and Aguas CAP-EPA SpA.
- Pilot scale RH2 project.
- Located in the Antofagasta Region.
- With 2 GW of renewable solar power, an electrolysis capacity of 1 MW will be supplied to produce 60 tons of RH2/year.
- RH2 for transport use.

Proyecto H2V Inversiones Farias [325]
- By Inversiones Farias.
- Located in the Antofagasta Region.
- RH2 production through a 0.01 MW electrolysis capacity.

Estación de hidrógeno aeropuerto [326]
- By Nuevo Pudahuel, Air Liquide, Copec, and Colbún.
- Located in the Metropolitan Region.
- RH2 production through a 0.1 MW electrolysis capacity to produce 7 tons of RH2/year. Expected to begin operation in 2025.

Llaquedona (previously Selknam project) [62]
- By Sociedad de Inversiones Albatros, Alfanar, and CIP.
- Located in the Magallanes region.
- 1,150 MW in renewable power capacity will supply an expected production capacity of 85 kt RH2/year and 500 kt NH3/year. Operation is expected to begin in 2027.

Chile

Under development

- RH2 for ammonia export.

Cerro dominador [62]
- By Grupo Cerro.
- Located in the Antofagasta Region.
- 210 MW in installed concentrated solar power and PV capacity will supply 6 MW of electrolysis capacity to produce 950 kt RH2/year.

Mowi UACH [62, 327]
- By Mowi Chile and UACH.
- Pilot scale RH2 project.
- Located in the Aysén region.
- This project seeks a pre-feasibility analysis to replace the current diesel fuel consumption in the operation of Piscicultura Fiordo Aysén with locally produced RH2.

Renewstable Kosten Aike [62]
- By HDF and Eolica Kosten Aike SpA.
- Located in the Aysén region.
- 36 MW of installed wind energy capacity will supply renewable energy to produce 900 tons of RH2/year.
- The project aims to supply non-intermittent electricity to the Aysén isolated grid from renewable resources using RH2, fuel cells, and energy storage technologies.

METH2 Atacama [2]
- By Sowitec.
- Located in the Antofagasta region.
- 300 MW of electrolysis capacity to produce 78 tons of NH3/year.
- RH2 for methanol production.

HYDRA [62]
- By Engie, Mining3, Ballard, CSIRO, Reborn, Antofagasta Minerals, and Mitsui.
- Pilot scale RH2 project.
- Located in the Antofagasta Region.
- Considers replacing the internal combustion engine of large capacity mining haul trucks with a hybrid system of hydrogen fuel cell and batteries, replacing about 3,000 L of diesel consumption per truck per day.

H2-powered train [328]
- By FCAB.
- Pilot scale RH2 project.
- Located in the Antofagasta Region.
- RH2 powered train.

HIF Proyecto Faro del Sur [62, 329]
- By HIF, Enel Green Power, Siemens, Gasco, ENAP, Porsche, and Exxon Mobile.
- Industrial scale RH2 project.
- Located in the Magallanes Region.
- Through 300 MW wind power capacity and 240 MW electrolysis capacity, 70,000 m3 e-gasoline/year is expected to be produced. CORFO contribution: 16.9 MUSD. Haru Oni is its pilot project.
- RH2 for e-fuels (e-methanol and e-gasoline) for export.

Cabo Negro [330]
- By ENAP.
- Pilot scale RH2 project.
- Located in Cabo Negro, Magallanes Region.
- 1-2 MW electrolyzer, expected to begin operation in 2025. This project seeks to generate knowhow and experience in the production of this clean fuel within the company.

Power-to-MEDME [331]
- By Fraunhofer Chile, Fraunhofer ISE, and Fraunhofer IEE.
- Pilot scale RH2 project.
- Located in northern Chile.
- RH2 for synthetic fuels, including methanol and DME. DME will be used in the mining industry for heat processes and diesel replacement in heavy-duty vehicles.

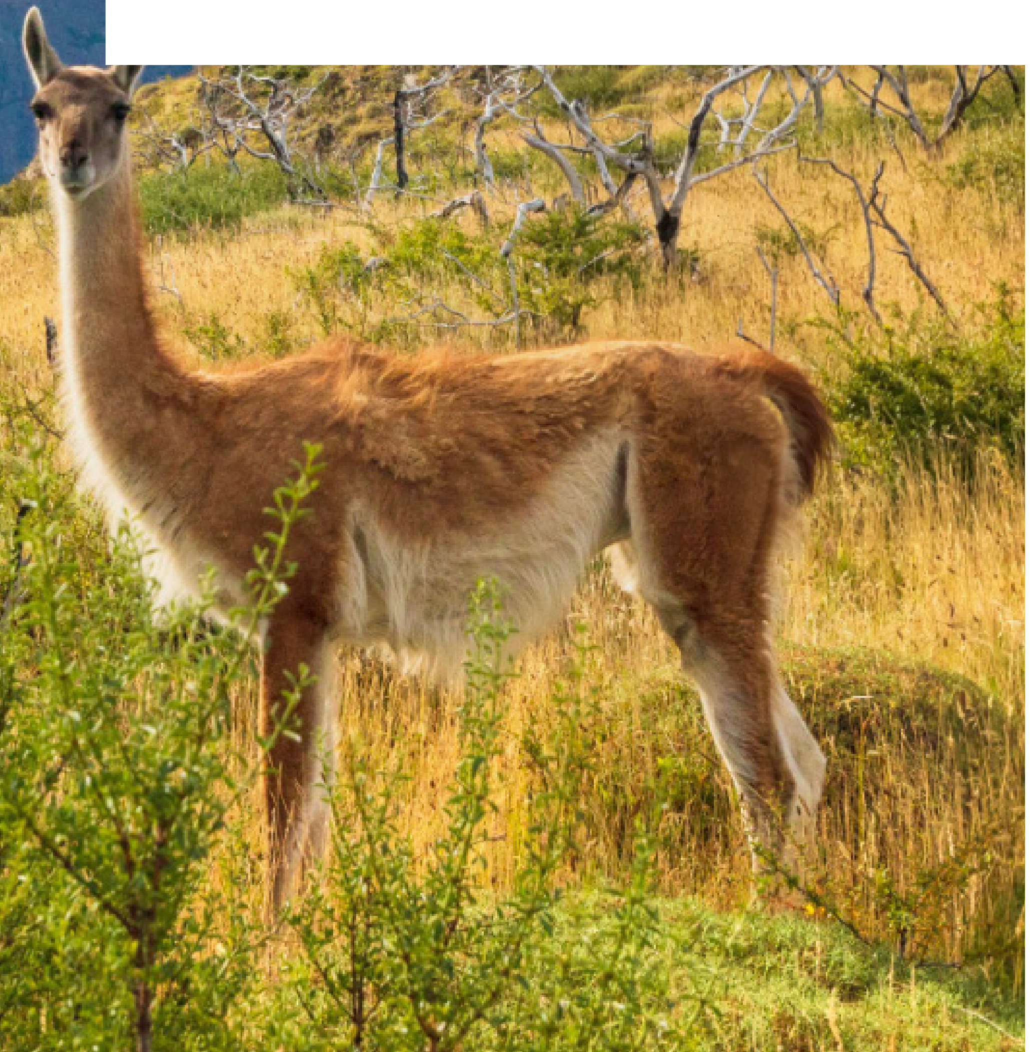
Chile

Under development

Volta [332]
- By MAE Energy.
- Industrial scale RH2 project.
- Located in Mejillones, Antofagasta Region.
- Using 600 MW in solar PV, a production capacity of 290 tons of NH3/year is expected. Operation is expected to begin in 2027.

Frontera [333]
- By Free Power
- Located in the Magallanes Region.
- RH2 for ammonia production.

Green Pegasus [334]
- By Glenfarne Energy Transition and Samsung Engineering.
- Solar PV of 2 GW capacity will supply renewable electricity to produce 89 kt RH2/year and 459 kt NH3/year.



Colombia

In operation

Ecopetrol 50kW electrolyzer [28, 58, 280]
- By Ecopetrol.
- Pilot scale RH2 project.
- In operation since first half of 2022.
- Private sector-led R&D. 50kW PEM electrolyzer in Cartagena Refinery, 20 kg H2/day. It aims to replace current use of grey H2 in the refining process. The project uses industrial water from the refinery to produce RH2. This test will allow compiling information on the operation, maintenance, reliability and scalability of the technologies used.

Promigas [28, 72, 280]
- By Promigas and Surtigas.
- Pilot scale RH2 project.
- In operation since 2022.
- Uses solar power to produce 1.5 t H2/year using 53.2 kW PEM electrolyzer. H2 injection into natural gas grid.

Ecopetrol H2 bus [73]
- Pilot scale RH2 project.
- In operation since March 2023.
- First public transport hydrogen bus in Latin America, with 500 km autonomy. Private sector-led R&D. 165 kW PEM electrolyzer in Bogotá, 65 kg RH2/day. It aims to test the technology and identify the regulatory and technical requirements to develop the hydrogen transport sector.

Ecopetrol FC vehicle [75]
- Pilot project, In operation since March 2023. light vehicle fuel cells. Private sector-led R&D. Toyota Mirai in Cartagena. It aims to test the technology and promote knowledge in terms of production and management of hydrogen in Cartagena's innovation center.

Opex [28, 74]
- Pilot scale RH2 project.
- In operation since July 2022.
- First light vehicle fuel cell. Private sector-led R&D. Hyundai Nexo in Medellín 1,000kgRH2/day. It aims to test the technology and promote knowledge in terms of production and management of hydrogen.

Under development

Ecopetrol pilot 1 [28, 280, 335]
- By Ecopetrol.
- Pilot scale RH2 project.
- In Cartagena refinery. Feasibility development of new renewable or blue hydrogen plants at the refineries, with capacities of 40-60 MW each. Expected to begin operation in 2026.

Ecopetrol pilot 2 [28, 280, 336]
- By Ecopetrol and EDF.
- Pilot scale RH2 project.
- In Barrancabermeja refinery. 60 MW electrolysis power. Expected to begin operation in 2026.

Proyecto META [28]

OCENSA [28]

MEC H2 [28, 337]
- The purpose of the MEC-H2 project is to develop a model of the Colombian energy system to assess of energy transition scenarios and mitigation of greenhouse gas emissions in the long term as a decision-making tool to make the green hydrogen and blue hydrogen economy viable, supplying the future demand of various sectors of the economy and considering the technical, environmental, economic, social and regulatory impacts.

Sebastopol Refinery [28]
- 60 MW

Celsia [28]
- Pilot scale RH2 project.

Promigas [338]
- By Promigas.

Under development

• Pilot scale RH2 project.
• RH2 for mobility.

TGI [338]
• By TGI.
• Pilot scale RH2 project.
• RH2 for internal combustion engines.

Barranquilla Project [339]
• By Alumbrado Público de Barranquilla and Monómeros S.A.
• Located in Barranquilla.
• Renewable energy from an offshore wind farm will be used to produce ammonia. Operation will begin in 2026.
• Ammonia use for fertilizer production to be sold to the Colombian agriculture sector, reducing dependence on imports from other countries.

Prothium [340]
• By OPEX and Hevolucion.
• The project is currently under execution.
• The energy source is a small hydroelectric power plant to supply a 2.3 MW alkaline electrolyzer. The final product will be ammonia.

Deuterium [340]
• By OPEX and Hevolucion.
• The energy source is a small hydroelectric power plant to supply a 5 MW alkaline electrolyzer. The final product will be ammonia.
• The project has reached the final investment decision.

Green Urea Project [340]
• Concept studies developed by Technip Energies and supported by the IDB.
• The project will use a 30 MW alkaline electrolyzer to produce renewable urea.

Green ammonia mobility project [340]
• 1 MW alkaline electrolyzer to produce ammonia.
• The project is currently under feasibility studies.

TW Solar project Sucre [340]
• Includes a 3 GW PEM electrolyzers to produce renewable hydrogen and ammonia.
• The project is currently at concept design.

Hydrogen export Project [340]
• By TGI SA ESP, IDB, IDB INVEST, and GEB.
• Includes a 140 MW electrolyzer. The final products will be hydrogen, ammonia, and metanol.

AES Project [340]

HRS hydrogen refueling station [340]
• By TW Solar and Fendipetroleo.
• Includes a 2 MW PEM electrolyzer.

HUB hidrogeno Atlántico II [340]
• By TW Solar.
• Includes a 100 MW PEM electrolyzer.
• RH2 for ammonia production, refineries, and other industrial uses.

HUB hidrogeno verde Cartagena [340]
• By TW Solar.
• Includes a 40 MW PEM electrolyzer.
• RH2 for ammonia production and refineries.

HUB Barranquilla [340]
• By TW Solar, Atlantic Energy Group, Royal Port, Aqua Mar, Wattnier, Arquitectura Eco, and Universidad del Norte.
• Includes a 100 MW PEM electrolyzer.
• RH2 and ammonia production.

Optimization of a multifluid system for parallel generation and sale of electricity and green hydrogen and associated services for industrial customers [340]
• By VATIA SA ESP,
• Includes a 1.2 MW PEM electrolyzer.

Costa Rica

In operation

Costa Rica Sustainable Transportation Ecosystem [2, 23, 47, 48, 229]

- By Ad Astra and RECOPE.
- Pilot scale RH2 project.
- In operation since 2013.
- RECOPE (the Costa Rican Oil Refinery) and Ad Astra started development of an experimental hydrogen production and storage plant; in 2011 feasibility studies were conducted and, design and construc-tion began in 2012. Between 2014 and 2017, infrastructure was expanded and renamed the “Costa Rica Sustainable Transportation Ecosystem”, with the support of Costa Rica’s Development Bank Sys-tem and private partners. It produces H2 from renewable electricity (wind and solar energy) to power the region's first H2 fuel cell vehicles (1 fuel cell bus and 4 fuel cell light-duty vehicles.) and pro-duce 0.8 t H2/year from solar and wind power. It uses a 5 kW PEM electrolyzer. Currently the company produces about 2.5 kg of H2 per day. It owns an 80-kW solar and wind farm generating renewa-ble electricity for H2 production. H2 storage at 450-700 bar with ongoing expansion to 900 bar. A 350-bar hydrogen dispensing station is currently being expanded to 700 bar fast refueling capability for private automobiles (such as the Toyota Mirai) as well as urban bus operations.

FC bus [48, 229]

- By Cummins Inc (owner) and Relaxury SA (operator).
- Pilot scale RH2 project.
- 1 Van Hool A330 35-passenger fuel-cell urban bus.

FC cars [48, 229]

- By Purdy Motor SA.
- Pilot scale RH2 project.
- First fuel-cell passenger cars introduced into the Latin American market.
- 4 units; Toyota Mirai sedans.

Under development

H2 project [23]

- RH2 project.
- By Ad Astra and Invermaster.

FC trucks [48, 229, 341]

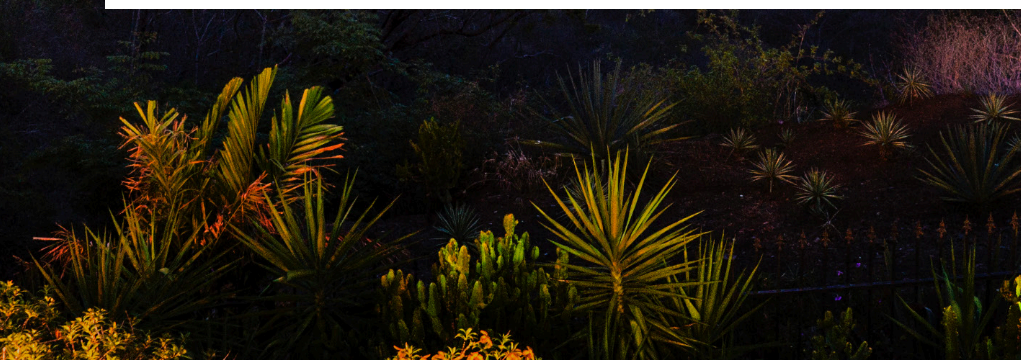
- NAMA Support Project titled “Green Hydrogen for a Decarbonized Economy” led by the German International Cooperation Agency (GIZ) on behalf of the Ministry of Environment and Energy (MI-NAE).
- Pilot scale RH2 project.
- 10 FC trucks.

FC cars [48, 229]

- 10 FC cars.

H2 project [342]

- By Cavendish (Grupo Purdy).
- Industrial scale RH2 project.
- Located in the city of Limón or on the Pacific coast.
- Production would be of 400,000 tons of RH2-based fertilizer. The start of the project is pending due to an agreement with the state company ICE.



Mexico

Under development

Dhamma Energy Guanajuato [28, 280]
- PV power will supply a RH2 plant to produce 12.6 kt RH2/year through 100 MW of electrolysis power. Expected to begin operation in 2026.
- Hydrogen offtakers for electromobility (passenger vehicles, buses, ships, trains, etc.) and industry (cement, refineries, steel manufacturers, etc.).

Delicias Solar [28, 280, 343]
- Photovoltaic modules will power an RH2 plant with a nominal production capacity of 35 MW, capable of producing 6 kt RH2/year.

Energías Los Cabos [28, 280, 345, 346]
- By HDF Energy.
- Located in Baja California.
- Solar PV coupled to a power-to-power system with energy storage in form of H2 and Li-Ion batteries to manage and cushion energy fluctuations. Annual energy production of 195 GWh. PV plant will supply a 25 MW PEM electrolyzer to produce 4 kt RH2/year. Expected to begin operation in 2024.

CFE Fuel Cells [28]

Mexican Green Hydrogen Hub [344]
- Solar PV would be used for ammonia production.

Tarafert II
- Tarafert, Ohmium.
- 347 MW of electrolysis power to produce 200 kt H2/year. Expected to begin operation in 2026.
- H2 for ammonia production.

Guanajuato Solar-H2V Project [345, 347]
- Industrial scale RH2 project.
- Located in Guanajuato.
- 120,000 PV modules with a capacity of 35 MW. The estimated electrolysis capacity is 100 MW and production of 3,205 Mt of RH2/year is expected. Currently, it is in intermediate stage of development; it depends on H2 regulations and public policies in Mexico to continue and reach the ready-to-build phase.
- RH2 will be injected into local gas pipeline infrastructure.

Durango project [345, 347]
- Industrial scale RH2 project.
- Total and direct investment is 1.2 BUSD. This project will create around 2,800 direct jobs and thousands of indirect and induced jobs during construction. It will create 250 direct jobs and over 1,000 indirect jobs during operation.
- RH2 for ammonia production to supply the fertilizer sector.

Project in Chihuahua [345, 347]
- RH2 demand-side project.
- RH2 for cement production.

Peru

In operation

Industrias Cachimayo (ENAEX) [2, 53]

- Industrial scale RH2 project.
- In operation since 1965.
- Probably one of the world's oldest electrolyzer still in operation.
- 25 MW alkaline electrolyzer operating at Cachimayo for dedicated H2 production using grid electricity with a REC certificate.
- RH2 is used for ammonium nitrate manufacture.

Under development

Mmex Resources [348, 349]

- By Mmex Resources Corporation and Hydrogen Global LLC.
- Pilot scale RH2 project.
- Located on the south coast.
- Estimated production capacity of 55 tons of RH2/day, which will require 160 MW of constant renewable energy.
- H2 use for ammonia or methanol export.

Horizonte de verano [350]

- By Verano Energy.
- Estimated production of 2,100 kt RH2/year through 4.5 GW of electrolysis power. Operation is expected to begin in 2026.
- RH2 use for ammonia export or domestic use.

PLNG [351]

- By Perú LNG, Osaka Gas, and Marubeni.
- Production of synthetic methane from RH2 and CO2 capture from industrial sources or direct air capture.
- Products for export or internal use.

Engie Energía Perú-Ilo, Moquegua [352]

- By Engie Energía Perú.
- RH2 production to replace current grey H2 used to cool power plants. Operation is expected to begin in 2023.

Uruguay

Under development

H2U (former Verne project) [7, 33, 280]

- By Ancap, with the support of UTE and the Ministry of industry, Energy and Mining.
- Pilot scale RH2 project.
- Though it is a public sector initiative, the project seeks to fully involve the private sector to produce RH2 through electrolysis with electricity extracted from the national grid. It aims to meet a minimum of 1.5 MW of total nominal power of electrolyzers.
- RH2 to decarbonize heavy transport (at least 10 heavy-duty transport vehicles).

Tambor Green Hydrogen Hub [280, 353]

- By SEG Ingeniería.
- RH2 project.
- 300 MW of wind and solar power to produce 15 kt RH2/year, which will be converted into derivatives. The first phase will produce renewable e-methanol.

H2U Offshore ANCAP [280, 354]

- By ANCAP.
- Industrial scale RH2 project.
- Offshore wind farms will supply the RH2 plant.
- RH2 for export.

H2 trucks [233]

- By Grupo Santa Rosa, IVECO, and Nikola.
- H2-powered trucks; expected to arrive by the end of 2023.

H24U [355]

- By Saceem, CIR, and Air Liquide.
- Pilot scale RH2 project.
- Considers the installation of a solar PV plant, electrolyzer, construction of a refueling station, and the retrofitting of trucks. The project was awarded 10 MUSD from the Green Hydrogen Sector Fund.

HIF Paysandú [356]

- By ANCAP (ALUR) and HIF.
- Located in Paysandú.
- First e-fuels project in Uruguay.
- Through the installation of an alkaline electrolyzer with 1 GW of nominal electrolysis power, a production capacity of 250 M L e-gasoline/year and 100,000 tons of RH2/year is expected. Investment of 4 BUSD.
- E-fuels for export.

Renewable Hydrogen in Latin America and the Caribbean: Opportunities, Challenges, and Pathways

LAC Green Hydrogen Action