# Hydrogen in Latin America

## From near-term opportunities to large-scale deployment

International Energy Agency

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# Abstract

The momentum for low-carbon hydrogen is growing in Latin America, with many countries currently developing long-term hydrogen strategies and a project pipeline of more than 25 projects, including several gigawatt-scale projects to export it beyond the region. In this report we analyse both the region's potential to play a major role in the future low-carbon hydrogen landscape, and the role that low-carbon hydrogen could play in Latin America's own clean energy transitions. Low-carbon hydrogen deployment depends on many technologies that are still under development, and considerable cost reductions will be needed to enable it to reduce global emissions in applications that may not be suitable for director electrification. The next decade will be crucial for the long-term promise of low-carbon hydrogen in Latin America, and much can be done today to develop and demonstrate emerging technologies and prepare the ground for their future scaling up. We conclude the report with a series of six recommendations for policy makers in Latin America to harness the potential of low-carbon hydrogen in the region.

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# Executive Summary

Latin America[1] is one of the world's leading regions for renewable energy use today and one that can play a major role in the international push for low-carbon hydrogen, a crucial element of a global net-zero emissions future. In this context, low-carbon hydrogen has been gaining attention from policy makers in the region, mainly due to Latin America's long-term potential to produce large volumes of competitive low-carbon hydrogen and export it to other global markets. At the time of writing, 11 countries[2] in the region have either published or are currently preparing national hydrogen strategies and roadmaps, and a pipeline of more than 25 low-carbon hydrogen projects are at the early stages of development.

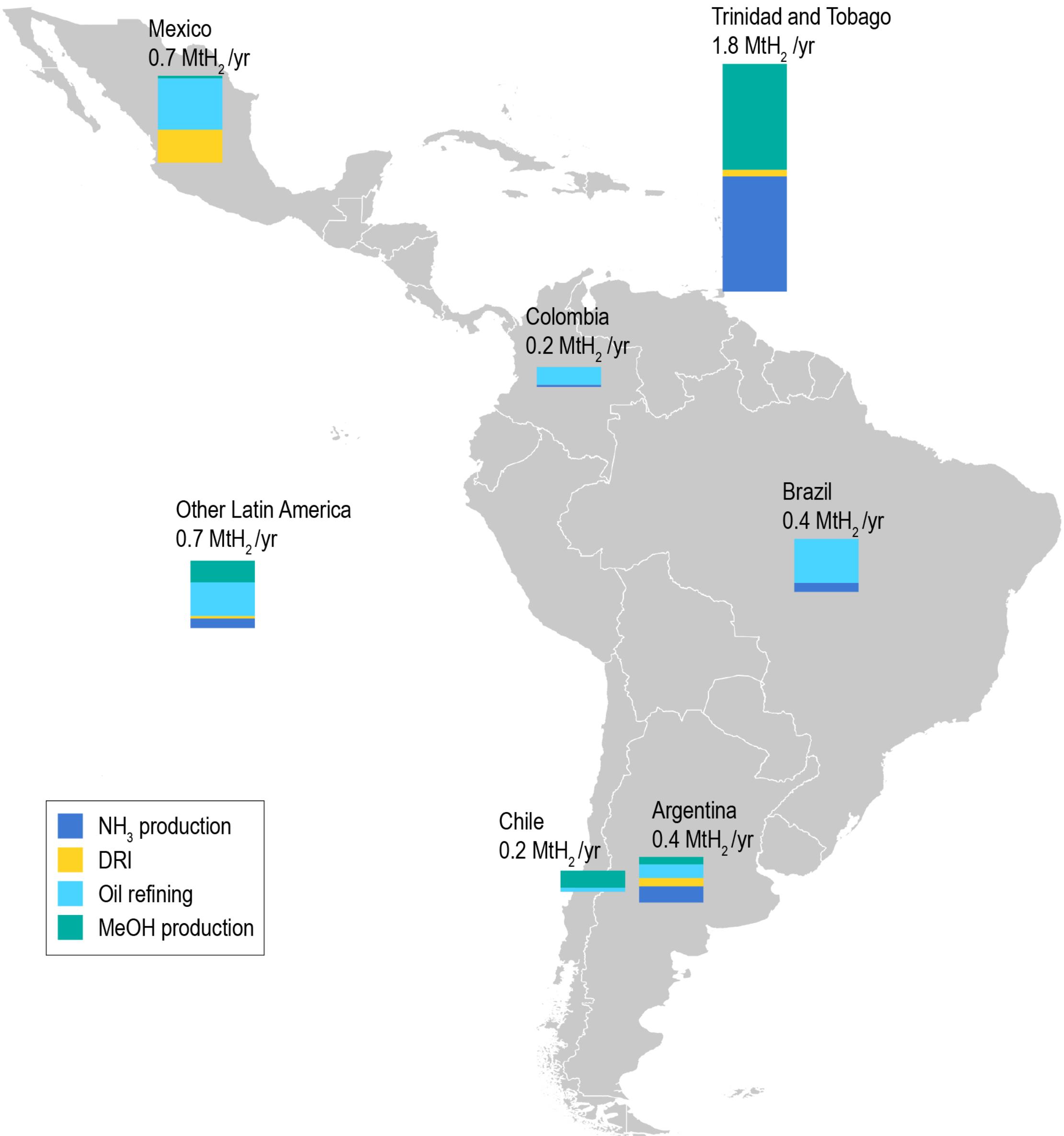
Low-carbon hydrogen can also play a crucial role in Latin America's own clean energy transitions, which have been gaining momentum in recent years, with many countries announcing ambitious new climate and energy goals and taking steps to translate these objectives into action. In the coming decade, variable renewables, energy efficiency and direct electrification will continue to drive emissions reductions in the region based on existing technologies. Beyond 2030, decarbonisation efforts will increasingly rely on technologies that are not commercially available today. These include low-carbon hydrogen applications that could substitute fossil fuels where direct electrification may present implementation challenges, and to further support the integration of renewables by providing long-term energy storage, among other applications. The next decade will be crucial for the development, demonstration and initial deployment of these emerging technologies, before they can be scaled up in a cost-competitive way.

Although hydrogen does not emit carbon dioxide ($CO_2$) at the end-use stage, current production processes are already responsible for large volumes of emissions in the region. Latin America's industrial and oil refining sectors required more than 4 Mt of hydrogen in 2019 (around 5% of global demand), mainly to produce ammonia, methanol, steel and refined oil products. In 2019 hydrogen production in the region required more natural gas than Chile's total gas supply, and released more $CO_2$ into the atmosphere than all of Colombia's road vehicles. Almost 90% of the region's hydrogen demand in 2019 was concentrated in the

[1] In this report, Latin America includes the Caribbean.
[2] Chile (published), Argentina, Bolivia, Brazil, Colombia, Costa Rica, El Salvador, Panama, Paraguay, Trinidad and Tobago, and Uruguay (in preparation).

region's five largest economies[3] and in Trinidad and Tobago, which alone accounted for more than 40% of total hydrogen demand.

**Figure 1 Hydrogen demand, Latin America, 2019**






Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

$NH_3$ = ammonia; MeOH = methanol; DRI = direct reduction of iron.

Administrative areas (boundaries) based on: GADM, version 1.0, https://www.diva-gis.org/gdata.

Sources: IEA analysis based on IEA statistics, data from the International Fertilizer Association, Wood Mackenzie, World Steel Association Steel Statistical Yearbook, Argentinian Petrochemical Institute Yearbook, ANP (Brazil) and Sistema de Información Energética (Mexico), among others.

[3] Argentina, Brazil, Chile, Colombia and Mexico.

In 2019 low-carbon hydrogen production was limited to three pilot projects in Argentina, Chile and Costa Rica. To meet the region's energy and climate goals, low-carbon hydrogen will have to replace existing carbon-intensive hydrogen production in the region and meet additional demand for new uses in the coming decades. Low-carbon hydrogen production could increase substantially based on the current project pipeline, which includes at least five large, gigawatt-scale projects to produce low-carbon hydrogen from renewable electricity, targeting export markets rather than domestic demand. To have an impact on Latin America's own clean energy transitions, local end-use sectors should also benefit from the region's competitive advantages in low-carbon hydrogen production, helping them reduce emissions, find new opportunities and create jobs in a net-zero emissions world. Hydrogen's versatility as an energy carrier allows each country to tailor its deployment strategy to its own context and long-term priorities, providing opportunities to leverage its own strategic advantages, industrial value chains, technological capabilities and infrastructure.

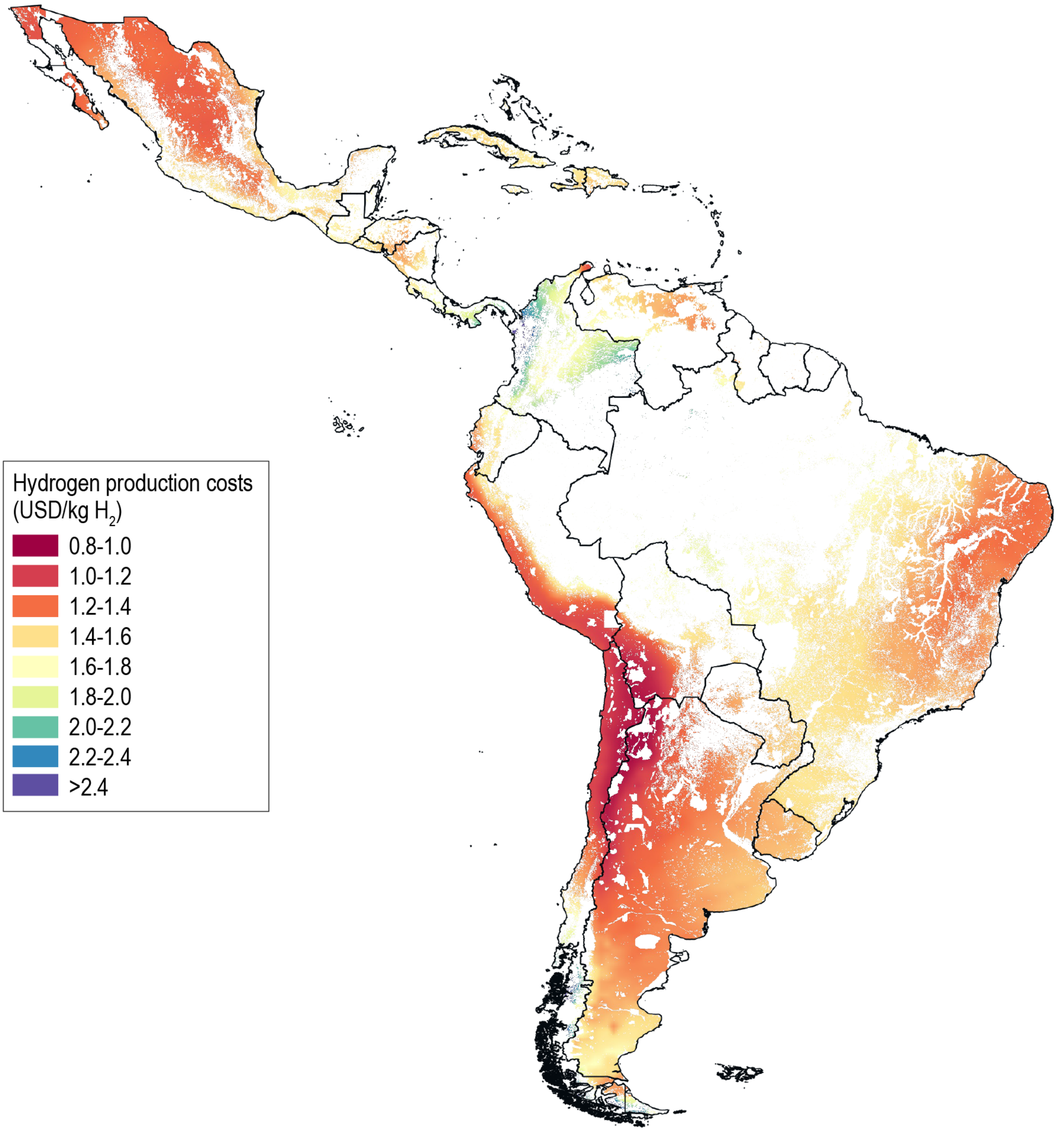
## Low-carbon hydrogen has the long-term potential to reduce emissions and unlock new trade opportunities

Low-carbon hydrogen could be one the drivers of the next phase of Latin America's clean energy transitions, by replacing fossil fuels in end uses that are not suitable for direct electrification. This includes low-carbon hydrogen applications in industry and transport with few decarbonisation pathways (e.g. steelmaking and long-distance shipping), as well as some applications where it will complement and compete with other sustainable technologies (e.g. road transport).

Certain low-carbon hydrogen uses may not be relevant in all countries, but could be crucial to reduce emissions for some of them. Practically all of the region's countries will need to decarbonise transport to meet their energy and climate ambitions and could find opportunities to deploy hydrogen technologies in this sector. In contrast, opportunities in heavy industry are concentrated in a few countries, where current activity is responsible for large shares of emissions. Brazil and Mexico produced more than 80% of the region's steel in 2019. Around half of Trinidad and Tobago's emissions come from its chemical industry, which produces and consumes large volumes of hydrogen from unabated fossil fuels. In Chile and Peru, low-carbon hydrogen uses in mining could displace large volumes of diesel and enable significant emissions reductions in the long term. Latin American countries could also find opportunities to leverage existing industrial and technological capabilities, value chains and infrastructure and as a part of their long-term low-carbon deployment strategy.

Some countries in Latin America have the potential to produce more low-carbon hydrogen than they can consume, thanks to their abundant and competitive renewable energy resources. Chile has the ambition to produce and export the world's most competitive hydrogen from renewable electricity by 2030, and many countries in Latin America share the conditions that could make the region a global leader in low-carbon hydrogen production. Fossil fuel producing countries could also find opportunities to build on their existing production and infrastructure to produce low-carbon hydrogen, for example by capturing and storing carbon emissions from existing hydrogen production facilities. In certain countries, such as Brazil, the availability of biogenic carbon from existing biofuels and bioelectricity production facilities could also help produce and export synthetic fuels, which require both carbon and hydrogen.

**Figure 2 Levelised cost of hydrogen production via electrolysis powered by hybrid solar PV and onshore wind, Latin America, 2050**






Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Assumptions: Electrolyser CAPEX = USD 232-341/kW (onshore wind and solar PV); solar PV CAPEX = USD 325/kW; onshore wind CAPEX = USD 1 200/kW; electrolyser LHV efficiency = 74%; electrolyser OPEX = 3% of CAPEX; system lifetime = 33 years; discount rate = 6%.

Administrative areas (boundaries) based on: GADM, version 1.0, https://www.diva-gis.org/gdata.

Weather datasets: Wind data: Copernicus Climate Change Service (2020), ERA5 hourly data on single levels from 1970 to present, https://doi.org/10.24381/cds.adbb2d47, European Centre for Medium-Range Weather Forecasts. Solar PV: renewables.ninja, www.renewables.ninja.

Exclusion zones based on: ESA and UCL (2011), *GLOBCOVER 2009: Products description and validation*; USGS (1996), *Global 30 Arc-Second Elevation (GTOPO30)*; Global Lakes and Wetlands Database (GLWD): Lehner and Döll (2004), "Development and validation of a global database of lakes, reservoirs and wetlands", *Journal of Hydrology*, Vol. 296, Issues 1–4, 20 August 2004, pp. 1-22; FAO-UNESCO (2007), *The Digital Soil Map of the World*; WDPA (2020), December 2020.

For some countries, this could unlock opportunities to export low-carbon products that are manufactured using low-carbon hydrogen, such as ammonia or steel, which are already traded internationally and may benefit from carbon adjustment mechanisms in some markets in the coming years. Increased trade can also benefit countries that may not have the conditions to export low-carbon hydrogen, such as Panama, which lies at the intersection of major maritime trade routes and is projecting itself as a hydrogen distribution hub for the region.

Encouraging the installation of value chains to manufacture equipment (e.g. electrolysers and fuel cells) could not only help reduce production costs, but also create highly qualified jobs and economic opportunities for the region, and could be pursued as an industrial policy objective.

Finally, low-carbon hydrogen can also play a role in increasing energy security and further integrating renewables in power systems. Hydrogen produced from renewable electricity can replace natural gas imports in certain countries. It can also provide seasonal and inter-annual electricity storage using surpluses of renewable energy in a region with large shares of hydropower and can provide stable renewable power supply in isolated systems and islands.

## Deploying low-carbon hydrogen in Latin America will be a complex challenge

The long-term deployment of low-carbon hydrogen production and applications is a complex challenge for Latin America, which will require working on multiple fronts simultaneously and in a co-ordinated way. This can only be achieved with the long-term engagement of all relevant stakeholders, including governments, industry, research and innovation agencies, financial services, trade unions and civil society.

In contrast with the recent deployment of variable renewables in the region, low-carbon hydrogen production and uses depend on many technologies that are not currently mature. Policy makers will therefore need to design adapted measures to support these sustainable technologies as they reach the market, as well as wider policies such as carbon pricing to provide long-term economic signals. Latin America can draw from its own experiences in developing and deploying clean energy technologies, such as biofuels for transport in Brazil. The recent deployment of variable renewables in the region was able to rely on existing electricity markets and supporting infrastructure for its product to reach consumers. In contrast, demand for low-carbon hydrogen will depend on the simultaneous and co-ordinated uptake of emerging end-use technologies and enabling infrastructure, making it more similar to the introduction of natural gas as a fuel in the region.

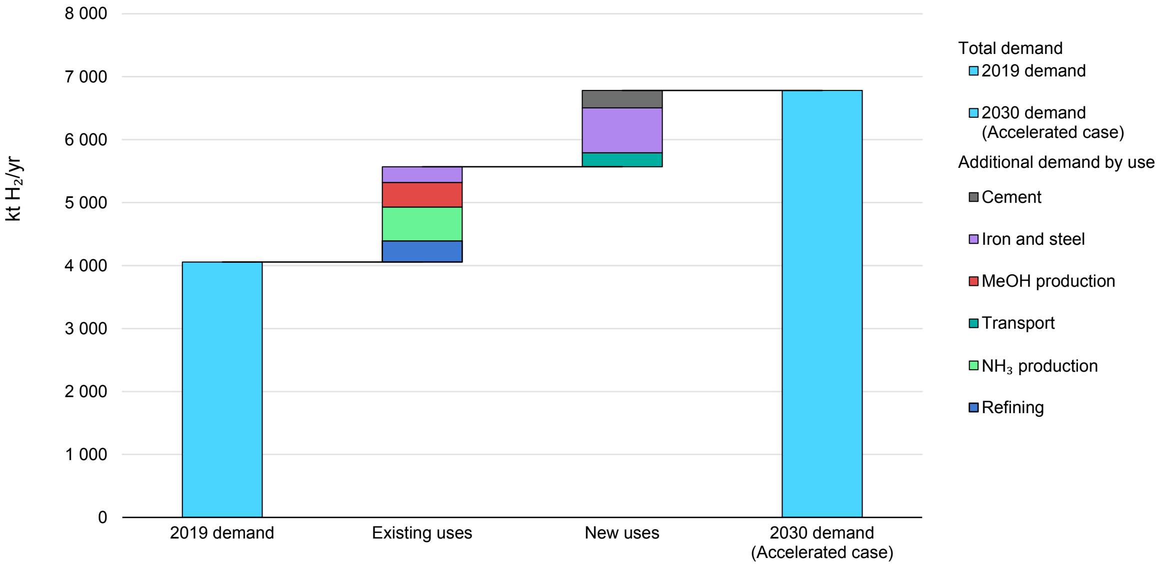
Scaling up low-carbon hydrogen and use will require timely investments in enabling infrastructure, including new transmission lines (for low-carbon electricity to reach the electrolysers for on-grid projects), hydrogen transport and storage infrastructure and port terminals. New value chains will be needed to support this scaling up, such as the installation of electrolyser manufacturing plants in the region, creating jobs and economic opportunities. This will require an early focus on education to develop the skills and capabilities that will be needed in this sector.

## The next decade will be crucial to secure the long-term potential of low-carbon hydrogen in Latin America

There is a lot the region can do today to secure its place in tomorrow's low-carbon hydrogen landscape. During the coming decade, initial efforts should focus on supporting R&D, pilots and the initial deployment of low-carbon hydrogen production and consumption technologies, and on preparing the ground for their large-scale adoption in the longer term. For countries that project themselves as future exporters, establishing internationally compatible certification and guarantees of origin schemes, as well as co-ordination mechanisms with future trade partners, would allow countries to capture emerging trade opportunities for low-carbon hydrogen and derived products.

Existing uses of hydrogen will, however, continue to dominate demand to 2030 in Latin America, with new uses in industry and transport representing less than 20% of total potential hydrogen demand. These existing uses could absorb growing shares of low-carbon hydrogen, replacing emissions-intensive alternatives and supporting the production of low-carbon hydrogen in the near term, without additional investment in end-use infrastructure.

**Figure 3 Change in hydrogen demand by sector, Accelerated case, Latin America, 2019-2030**






Note: The Accelerated case reflects an optimistic vision for the deployment of hydrogen end-use technologies to 2030, assuming that more ambitious energy- and climate-related policies are put in place and that the required techno-economic and infrastructure progress for the analysed applications will be achieved by that year.

Sources: IEA analysis based on IEA statistics, country surveys and data from the International Fertilizer Association, Wood Mackenzie, World Steel Association Steel Statistical Yearbook, Argentinian Petrochemical Institute Yearbook, ANP (Brazil) and Sistema de Información Energética (Mexico), among others.

Developing safety and technology standards is a prerequisite for hydrogen use in new applications, especially when these take place close to the consumer, such as in fuel cell vehicles or hydrogen use in buildings. Certain low-carbon hydrogen technologies, such as fuel cell vehicles, will also face a “chicken and egg” dilemma from an early stage, in the sense that their adoption will depend on the supporting infrastructure coming online in a timely way. Low-carbon certification and guarantees of origin schemes should also be an early priority, as they take years to fully develop and implement. These schemes can encourage local demand for low-carbon hydrogen and, in the longer term, unlock international trade opportunities for the region (provided these schemes are recognised by trading partners).

In the coming decade, retrofitting existing hydrogen production facilities with carbon capture and storage could be the most competitive low-carbon production route in many locations, especially for those that require large hydrogen volumes and stable supply, such as ammonia plants and large oil refineries. But, crucially, this depends on the availability of permanent $CO_2$ storage sites and infrastructure. Many countries may also find opportunities to start producing hydrogen from water and low-carbon electricity, a technological route that is expected to become the most competitive low-carbon option in the region in the medium to long term as renewable generation and electrolysers become increasingly affordable.

Public resources will be needed for R&D and demonstration projects, and to support the early adoption of emerging hydrogen technologies, as these low-carbon technologies will (almost always) be more expensive than high-carbon alternatives. As technologies develop and reach cost-competitiveness, economic support measures can gradually be removed and replaced by regulatory measures.

# Recommendations for policy makers

In view of the complex challenges involved, policy makers will need to develop a tailored and carefully timed mix of policy and regulatory measures guided by strategic priorities to reap the benefits of low-carbon hydrogen. Each country has a different set of opportunities and challenges in relation to existing hydrogen demand and supply, potential low-carbon production routes and demand sectors, existing industrial value chains, infrastructure and ecosystems of market players, technological capabilities and financial services, to name a few crucial aspects. Strategic planning should therefore be informed by a careful analysis of the baseline, and a clear vision for the role of hydrogen in the national clean energy transition, as well as the country's position in the future global hydrogen landscape. Based on such studies, the publication of roadmaps helps create momentum for the public sector, private investors and academia to join forces towards the goal of turning the promises of hydrogen into reality.

In parallel with national planning efforts, the regional level presents additional opportunities that should be considered when determining focus areas for national action. During the initial R&D, piloting and early deployment phases, regional collaboration can accelerate learning and exploit synergies, reducing the time to market and ensuring adaptation of technologies to regional requirements. Large-scale hydrogen deployment has the potential to create a new industrial sector to produce high-tech equipment. Regional supply chains to manufacture equipment (such as electrolysers and fuel cells) could create opportunities and jobs beyond the largest economies. This highlights the importance of harmonised standards and certification schemes to facilitate international co-operation and trade. International dialogue and co-ordination will be important to foster the necessary connections among different stakeholders and market players, and position the region in the future low-carbon hydrogen landscape. Given its global ambitions, the region should actively participate in the initiatives that could shape future low-carbon hydrogen markets, such as the Clean Energy Ministerial Hydrogen

Initiative, the International Partnership for Hydrogen and Fuel Cells in the Economy, Mission Innovation Clean Hydrogen Mission and the IEA Hydrogen Technology Collaboration Programme.

Low-carbon hydrogen could represent a major opportunity for Latin America in a net-zero emissions world. This report makes six recommendations for policy makers in Latin America, who can take action today to secure these long-term opportunities:

- Define a long-term vision for hydrogen in the energy system.
- Identify near-term opportunities and support initial deployment of key technologies.
- Support early financing schemes and reduce investment risk.
- Focus on R&D and skills to reap benefits beyond emission reductions.
- Use certification schemes to incentivise the production of low-carbon hydrogen and create market opportunities.
- Co-operate regionally and internationally to position Latin America in the global hydrogen landscape.

# Introduction

## The case for hydrogen is clear in Latin America's energy future

Among the world's regions, Latin America has one of the highest shares of renewables in power generation. Hydropower is the leading low-carbon technology – in 2019 it accounted for more than 40% of Latin America's total electricity production. In the past decade, renewable generation has increased due to the large-scale deployment of variable renewables across the region. Onshore wind and solar photovoltaics (PV) in particular have seen rapid growth, with installed capacity growing more than fifty-fold between 2008 and 2019, benefiting from the region's high-quality and abundant renewable resources. In the coming decades, renewables and direct electrification will continue to drive emission reductions in Latin America, but hydrogen and other technologies could be needed to decarbonise energy uses beyond electrification.

Although hydrogen consumption does not lead to carbon dioxide ($CO_2$) emissions at the end-use stage, current hydrogen production routes from unabated natural gas (the most widespread globally and in Latin America) emit 8-10 tonnes of $CO_2$ per tonne of hydrogen, in addition to potential fugitive emissions of methane across the whole supply chain. Switching to low-carbon hydrogen production routes can reduce emissions from the production stage, which currently leads to large volumes of greenhouse gas (GHG) emissions. In the future, emerging technologies could unlock new uses of hydrogen in applications that are not suitable for direct electrification, such as the production of steel, chemicals and cement, or certain forms of long-distance transport. Hydrogen can also facilitate further integration of renewables in power grids by providing significant flexible electrical loads, long-duration storage and flexible power generation. For these new technologies to actually lead to lower emissions, the hydrogen used must be low carbon.

**What is low-carbon hydrogen?**

Most of the hydrogen consumed in Latin America is produced through carbon-intensive processes such as natural gas reforming.

There are two main routes to the production of low-carbon hydrogen: preventing the escape of emissions generated from producing hydrogen with fossil fuels (for example, using carbon capture and storage); and using electrolysis to split water with low-carbon electricity, such as from renewables or nuclear. Latin America could have interesting opportunities to explore along both routes, leveraging its existing fossil fuel production and reserves, and its abundant renewable resources.

Coupling conventional technologies with carbon capture, utilisation and storage (CCUS) technologies is currently the main route to producing low-carbon hydrogen globally. It is likely to remain so in the short to medium term as its production costs are lower than other low-carbon technologies. Depending on process characteristics and the technologies used, it is thought that more than 90% of the $CO_2$ emissions associated with hydrogen production could potentially be captured, although these capture rates are yet to be demonstrated at an industrial scale. The ability to deploy CCUS critically depends on the availability, suitability and cost of $CO_2$ transport and storage infrastructure. Large industrial facilities, or plants in the vicinity of other carbon-emitting activities that need to be decarbonised, could benefit from higher infrastructure utilisation rates leading to lower costs. Using captured $CO_2$ in products does not necessarily reduce emissions, and careful life-cycle assessment is needed to ensure they deliver climate benefits.

Electrolysers produce hydrogen from electricity and water. For hydrogen from water electrolysis to be low carbon, it must be produced using low-carbon electricity, including from variable renewables, hydropower and nuclear, or a combination of them. While electrolysers are a well-known and long-used technology in a variety of industrial sectors, scaling up their deployment to meet energy and climate objectives is likely to require cost reductions and increased efficiency. Such a scale-up would also need significant investment in new and affordable low-carbon generation to power the electrolysers (in addition to the extra capacity needed to further decarbonise power generation in many countries).

As is the case for all new technologies, safety standards are an essential pre-condition to increasing the role of hydrogen in energy systems. This is especially the case for applications closer to consumers, such as in road vehicles, to avoid accidents and foster social acceptability.

Ensuring that hydrogen production is low carbon will require an early focus on certification processes. This is essential to guarantee that its use results in lower emissions – because in most countries hydrogen produced solely from grid electricity would be more emissions intensive than hydrogen from natural gas without CCUS (unless production only operates in periods of no or very low fossil-based generation). Additionally, certification would help make low-carbon hydrogen an attractive option for consumers and companies looking to reduce their carbon footprints, including for environmental, social and governance (ESG) initiatives in the private sector. From the outset, certification mechanisms should be harmonised internationally and be comparable across energy carriers, including renewable electricity, natural gas and biomethane.

International compatibility will enable Latin America to access future export markets for premium products, such as low-carbon steel, ammonia and fertilisers, as well as provide possible opportunities for low-carbon hydrogen exports to other parts of the world. In the longer term, abundant biomass resources from the region's agro-industrial and bioenergy sectors could also be harnessed to produce synthetic fuels using biogenic carbon, in combination with low-carbon hydrogen.

The five largest Latin American economies (Argentina, Brazil, Chile, Colombia and Mexico) already produce large volumes of hydrogen from unabated fossil fuels for use in the chemical and iron and steel industries, and in oil refineries. These countries are also home to the largest and most diversified industrial sectors in the region, as well as the most developed natural gas infrastructure and, in some cases, significant fossil fuel resources. This gives these five countries the opportunity to explore a wider range of options for low-carbon hydrogen in both existing and new end uses, leveraging existing industrial capabilities and value chains. Moreover, these five countries – with a combined area three times that of the European Union – are home to high-quality wind and solar resources. These could allow them to produce large amounts of competitive renewable electricity in the future and, potentially, exportable volumes of low-carbon hydrogen.

Costa Rica, Paraguay and Uruguay currently produce virtually all of their electricity from renewables. In Costa Rica and Uruguay, this is the result of sustained policy efforts to replace imported fossil fuels with renewables, reducing emissions and improving energy security at the same time. In Paraguay, hydropower generation largely exceeds local demand, with excess generation exported to Brazil. In these countries, the next steps of decarbonisation will involve addressing emissions beyond the power sector. The transport sector, responsible for almost 80% of $CO_2$ emissions from fuel combustion in these countries in 2018, encompasses applications where hydrogen could play a role in the long term, alongside other sustainable mobility technologies.

In addition to being a major liquefied natural gas (LNG) exporter, Trinidad and Tobago is currently the largest hydrogen producer in Latin America, accounting for more than 40% of the regional total. Abundant natural gas has enabled the production and export of large volumes of ammonia and methanol, two base chemicals that use hydrogen as feedstock. Hydrogen production from unabated natural gas is responsible for a large share of total $CO_2$ emissions in Trinidad and Tobago, which is one of the world's largest emitters on a per-capita basis. Low-carbon hydrogen technologies could help reduce emissions using existing infrastructure and, in the future, unlock new export markets for low-carbon hydrogen and derived products.

And finally, there is also a case for hydrogen even in the absence of major consumption or production, namely in logistics and supply chains. Panama's strategic location at the crossroads of major shipping routes makes it a global hub for maritime transport and a centre for regional trade. Hydrogen production and consumption in Panama is currently very limited, and the country does not have the large renewable resources of some of its larger neighbours. In 2021 the Panamanian government presented a vision for the country to become a logistics and distribution centre for low-carbon hydrogen, initially focusing on the maritime shipping industry that could become an off-taker for hydrogen-based fuels in the future.

# The momentum behind hydrogen is growing in Latin America

Action in the next decade will be crucial for the long-term prospects of hydrogen in Latin America. Governments will play an important role in defining a long-term vision for hydrogen in their energy sectors and orienting its development towards its most strategic applications. As technologies develop, pilot projects will allow the region to identify and become familiar with hydrogen technologies, and then to make informed choices when these technologies become commercially available.

Moreover, discussions on the introduction of carbon border adjustment mechanisms in certain regions and expectations of increased demand for low-carbon goods, including hydrogen and derived products, could create opportunities for the region to leverage its potential for low-carbon hydrogen production and capture emerging trade opportunities.

Hydrogen is not a new topic in the region's energy landscape. In 2002 Brazil created the country's first Fuel Cell System programme (PROCaC) to develop fuel cell technologies domestically. Argentina passed its Hydrogen Promotion Law in 2006, declaring hydrogen production, energy use and R&D as activities of national interest. The country was also home to the region's first experimental plant in the city of Pico Truncado in 2005, followed by the first pilot project, Hychico, which has been producing electrolytic hydrogen from renewable electricity since 2008. In 2011 a second pilot project was launched in Costa Rica by Ad Astra Rocket to produce hydrogen from renewable electricity to power the region's first hydrogen fuel cell vehicles. Some countries have already published their own safety standards for hydrogen, including Argentina and Brazil, which participate in the International Organization for Standardization (ISO) hydrogen technical committee on hydrogen technologies (ISO TC 197).[1]

Since 2018 technological progress and ambitious policy announcements around the world have brought hydrogen back to the centre of the global energy debate, thanks to its potential to reduce emissions in sectors where emissions are hard to abate and as a future opportunity for international trade. As many of these applications are not technologically mature, ongoing R&D is crucial to unlock the full potential of hydrogen in key applications. In recent years many countries globally have published high-level strategic documents for hydrogen, providing a long-term vision for hydrogen's place in their energy sectors. These documents are crucial to prepare the ground for the large-scale deployment of hydrogen technologies in the long term (from 2030 onwards), when key technologies to scale up the use of hydrogen as an energy carrier could become commercially available.

This renewed interest in hydrogen has developed at a time when Latin America is stepping up its clean energy ambitions. In 2019 Costa Rica became the first country in the region to announce a net-zero emissions target for 2050, followed by Chile's carbon neutrality target for the same year, announced in 2020. Chile's Carbon Neutrality Plan for the Energy Sector foresees that hydrogen will be responsible for a 21% reduction in energy sector emissions by 2050. In late 2020 and early 2021 several countries in the region updated their nationally determined contributions for 2030 and publicly pledged to achieve carbon neutrality by 2050 (Argentina, Brazil, Colombia and Panama). Several regional initiatives have added to this momentum, such as the Renewable Energy for Latin America and the Caribbean (RELAC) alliance, through which 11 participant countries are collaborating to reach a regional renewable capacity target of 70% by 2030.

In 2018 Costa Rica published an inter-institutional action plan to promote hydrogen as a transport fuel. In November 2020 Chile became the first Latin American country to launch a comprehensive hydrogen strategy, positioning the

[1] ISO-IRAM 15916 (Argentina) and ABNT IEC/TS 62282-1:2018 (Brazil).

country as a clear frontrunner in the region. This was soon followed by two major low-carbon hydrogen project announcements in the country, initially aimed at replacing imported ammonia for applications in the mining sector (HyEx) and producing synthetic fuel from methanol (Haru Oni). Both projects include an initial pilot phase that is to be scaled up in a second phase to target export markets beyond the region.

The publication of the Chilean hydrogen strategy in November 2020 marked an acceleration in policy discussions around the region. In February 2021 the Brazilian National Council for Energy Policy (CNPE) established hydrogen as a priority area for R&D resources. Brazil's Energy Research Office (EPE) then released an initial technical document establishing the basis for a national hydrogen strategy, and CNPE tasked the Ministry of Mines and Energy, in collaboration with other entities, with preparing guidelines for a National Hydrogen Programme, which were presented in August 2021. In Argentina, an inter-ministerial group was created in 2021 to develop a hydrogen roadmap and update the existing hydrogen promotion law. Colombia's Ministry of Mines and Energy presented its national hydrogen roadmap for public consultation in August 2021. The governments of Bolivia, Costa Rica, El Salvador, Panama, Paraguay, Trinidad and Tobago and Uruguay are also in the process of developing hydrogen roadmaps and strategy documents.

National strategies are critical for establishing a long-term vision for hydrogen in a country's energy sector, and for identifying technological and policy potential and challenges. Regional co-operation on hydrogen, focusing on shared challenges and potential, could also help establish international supply chains in different parts of the hydrogen economy and amplify Latin America's voice in the global hydrogen discussion.

# Current status of hydrogen production and use in Latin America

## Regional hydrogen demand

Latin American countries have various levels of industrial development, with activity concentrated in the region's five largest economies (Argentina, Brazil, Chile, Colombia and Mexico), in Trinidad and Tobago and in Venezuela. In 2019 total hydrogen demand in the region stood at 4.1 Mt $H_2$, around 5% of the global total (which amounted to almost 90 Mt $H_2$ in 2020). These totals exclude additional volumes of hydrogen present in residual gases from industrial processes used for heat and electricity generation. Residual gases are not considered as hydrogen demand, since their use is not linked to any hydrogen requirement but to the inherent presence of hydrogen in these streams.

Hydrogen can be used as a pure gas in applications that tolerate only low levels of other gases or contaminants. It can also be used as part of a gaseous mixture with carbon-containing gases as a fuel or a feedstock in industrial processes (in this report we refer to it as "mixed hydrogen").

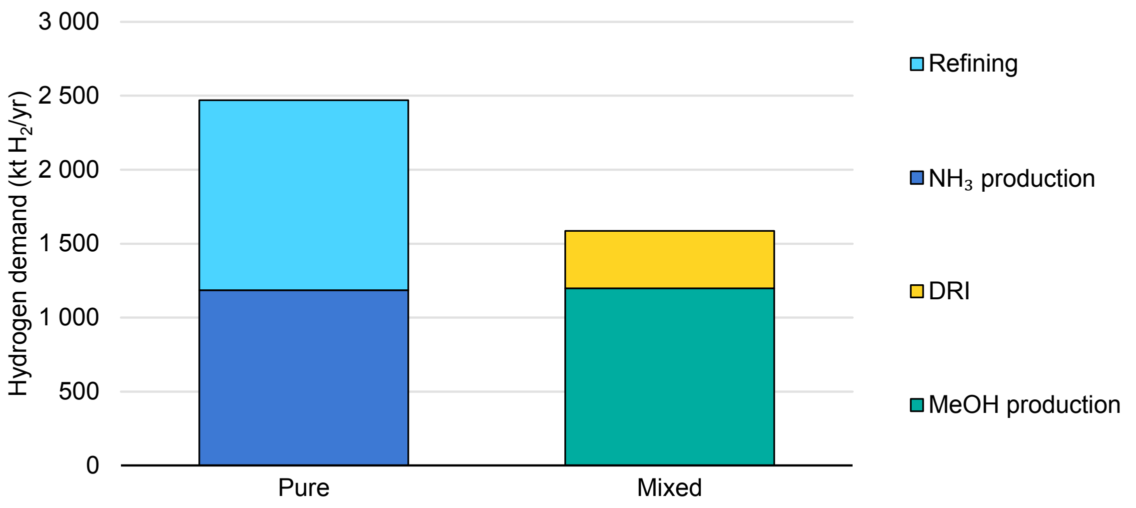
Captive or dedicated hydrogen production, in which production and consumption are integrated in the same process, is the most common supply route in Latin America and is complemented with small volumes of merchant production. As hydrogen is not traded across borders, demand is equal to supply in all countries. Latin American demand for pure hydrogen stood at 2.5 Mt $H_2$/yr in 2019, corresponding to 61% of total hydrogen demand. The main sources of pure hydrogen demand are ammonia production (1.2 Mt $H_2$/yr) and oil refining (1.3 Mt $H_2$/yr). Minor demand from other industries (such as electronics, food processing and glassmaking) and new uses (such as transport and power generation) are not included in these figures.

Almost a quarter of the ammonia produced in the region is used to manufacture urea, a fertiliser. In 2019 the region produced at least 2.5 Mt of urea and imported over 9 Mt from outside the region. The remaining three-quarters of ammonia production was exported to buyers outside the region or used to produce small volumes of other nitrogen fertilisers and explosives. In 2019 ammonia and urea production in Brazil and Mexico stood well below installed capacity due to competition from external producers, high gas prices (in Brazil) and difficulties in securing gas supplies (in Mexico).

In oil refineries, hydrogen is mainly used for upgrading heavy crudes and for desulphurisation, and hydrogen requirements vary depending on the sulphur content of the crude blends processed and the sulphur content specifications for refined products in each country. IEA data suggests that refineries in Mexico, Colombia and Ecuador tend to process more sour crude grades than in Argentina or Brazil, leading to higher hydrogen requirements per refined barrel of crude.

Regional demand for mixed hydrogen (with carbon-containing gases) stood at 1.6 Mt $H_2$/yr. This demand comes from applications such as methanol production (1.2 Mt $H_2$/yr) and direct reduced iron (DRI) steel production (0.4 Mt $H_2$/yr).

**Figure 4 Hydrogen demand by application, Latin America, 2019**

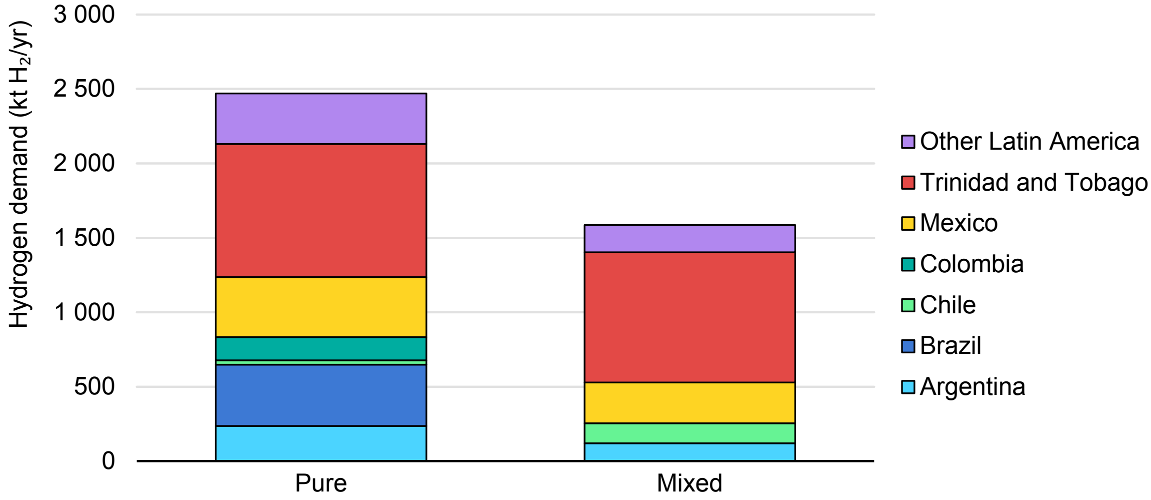





Notes: MeOH = methanol; $NH_3$ = ammonia.

Sources: IEA analysis based on IEA statistics, data from the International Fertilizer Association, Wood Mackenzie, World Steel Association Steel Statistical Yearbook, Argentinian Petrochemical Institute Yearbook, ANP (Brazil) and Sistema de Información Energética (Mexico), among others.

**Figure 5 Hydrogen demand by country, Latin America, 2019**






Sources: IEA analysis based on IEA statistics, data from the International Fertilizer Association, Wood Mackenzie, World Steel Association Steel Statistical Yearbook, Argentinian Petrochemical Institute Yearbook, ANP (Brazil) and Sistema de Información Energética (Mexico), among others.

Six countries in the region (Argentina, Brazil, Chile, Colombia, Mexico and Trinidad and Tobago) accounted for about 87% of the region's hydrogen demand in 2019.

Trinidad and Tobago alone accounts for around 44% of the region's total hydrogen demand, with total production of 1.8 Mt $H_2$ in 2019, and 50% of this being pure hydrogen. The chemical industry is responsible for 97% of the country's hydrogen demand, with large volumes of ammonia, methanol and urea produced for export, as well as small volumes for DRI production.

In Mexico, around 700 kt of hydrogen were produced in 2019. Oil refineries were the largest consumer of hydrogen, accounting for about 60% of total demand. The iron and steel industry, where hydrogen-rich synthetic gas is used for direct iron reduction, is the second-largest consuming sector in the country. Ammonia production fell by almost 70% between 2017 and 2018 and stopped completely in 2019 due to difficulties in securing sufficient gas supplies in parts of the country, before restarting at the Cosoleacaque petrochemical complex in 2020.

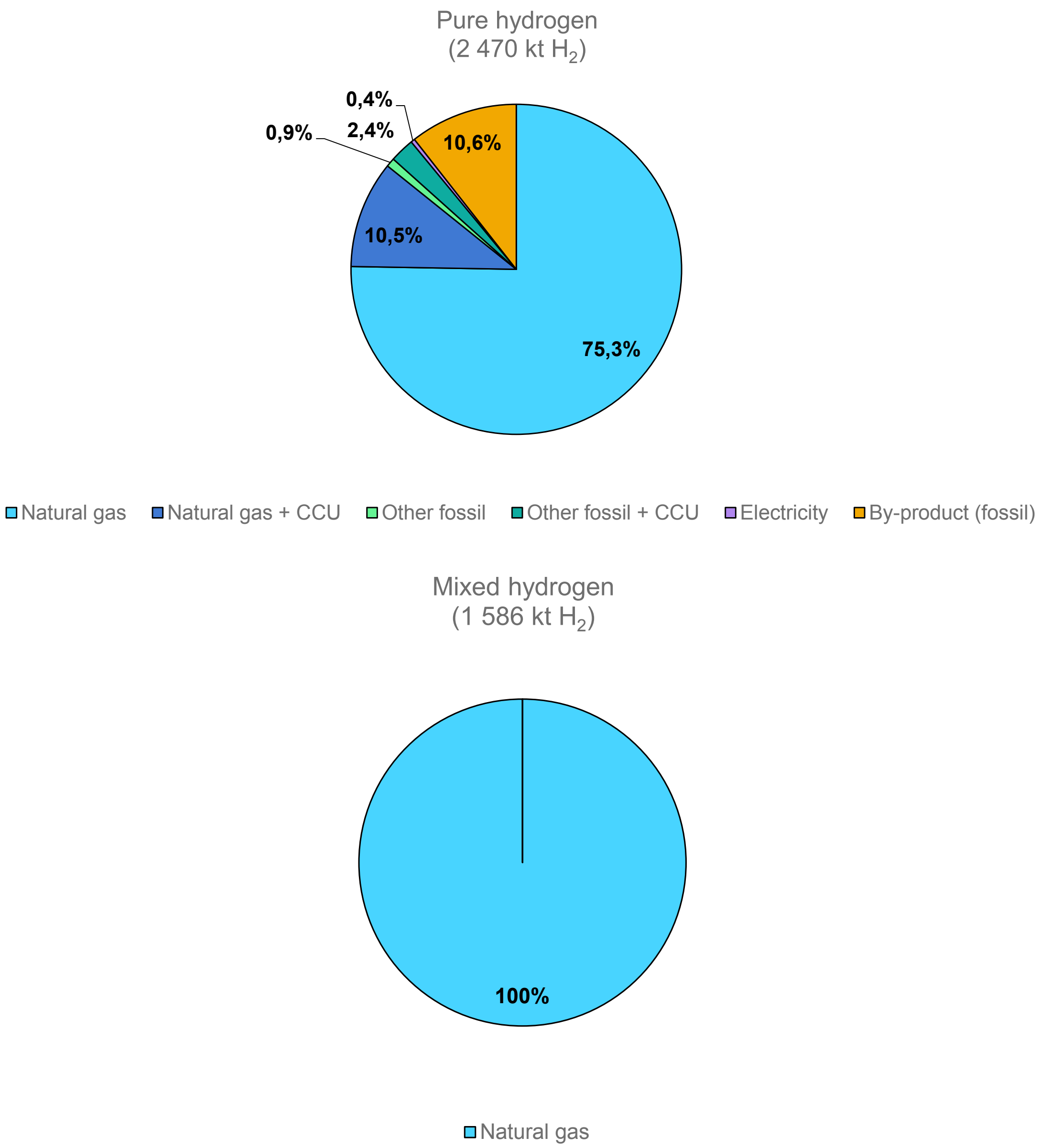
Brazil's hydrogen demand stood at about 400 kt in 2019. Virtually all of this demand was for pure hydrogen, with oil refining accounting for 83% of total demand. The remaining volumes were used for ammonia-based fertiliser production, an industry that operated well below its installed capacity in 2019. Three major fertiliser plants, in the states of São Paulo, Bahia and Sergipe, were idle in 2019 due to high gas prices and competition from foreign producers, leaving a fourth plant in Paraná as the only ammonia-based fertiliser production site in the country during that year. This underutilisation led to higher fertiliser imports to meet strong demand from the country's agricultural sector. Fertiliser production reportedly resumed at the Sergipe plant in April 2021.

Argentina's hydrogen demand amounted to about 350 kt in 2019, with two-thirds being pure hydrogen and the remaining third mixed hydrogen. Argentina is the only country in the region with sizeable hydrogen demand for all of the four main current applications of hydrogen in industry: oil refining and the production of ammonia, methanol and DRI. Most of the ammonia was used to produce urea, while some of it was exported as ammonia from the port of Bahía Blanca, where the largest plant is located.

Chile and Colombia together accounted for almost 8% of regional hydrogen demand in 2019. Oil refining is responsible for most of the demand in Colombia. Chile is the region's second-largest methanol producer, after Trinidad and Tobago, and hydrogen demand for this process corresponded to more than 80% of national demand in 2019.

# Regional hydrogen supply

**Figure 6 Regional supply of pure and mixed hydrogen by type, Latin America, 2019**






Note: CCU = carbon capture and utilisation.
Sources: IEA analysis based on IEA statistics, data from the International Fertilizer Association, Wood Mackenzie and World Steel Association Steel Statistical Yearbook.

To meet the 4.1 Mt of hydrogen demand from industry in Latin America, hydrogen production comes almost entirely from unabated fossil fuels without any capture and storage of the associated $CO_2$ emissions. A small amount of carbon emissions (less than 7%) are temporarily sequestered in the form of urea, but are released into the atmosphere at the end-use stage. Natural gas, in particular, is the main feedstock, accounting for 91% of total production in 2019. This represents a total estimated consumption of 15.5 bcm of natural gas in 2019 – more than Colombia's total natural gas consumption in the same year. This use of natural gas for hydrogen production without CCUS led to at least 32.5 Mt of $CO_2$ emissions in 2019, more than the total emissions from transport in Chile.[1]

Steam methane reforming (SMR) is used to produce hydrogen in refineries and industrial sites, as well as by merchant producers supplying smaller applications (including in the food industry and glassmaking). SMR for ammonia production leads to significant levels of emissions, most of them in concentrated streams. Part of these emissions is used in the production of urea in an integrated process, and temporarily sequestered in the form of urea before being released when it is applied to pastures as a fertiliser. In other words, while urea production is considered to include CCU, its use leads to significant emissions and should not be considered a low-carbon process. Decarbonising urea production, as well as the production of methanol (which requires both hydrogen and carbon), will require identifying a suitable (and low-cost) carbon source – either captured or biogenic.

Water electrolysis accounted for just 0.2% of total hydrogen production in 2019 and takes place in four facilities across the region, including three low-carbon hydrogen pilot projects and an industrial plant. In Cusco (Peru), Industrias Cachimayo has been producing hydrogen using a 25 MW alkaline electrolyser since 1965 to manufacture ammonium nitrate, used as a fertiliser and an explosive for the mining industry. This may be the largest electrolyser operating for dedicated hydrogen production using grid electricity in the world. Fossil fuels accounted for almost 40% of total electricity generation on Peru's power grid in 2018.

# Existing projects producing low-carbon hydrogen

Three pilot projects, in Argentina, Chile and Costa Rica, currently produce hydrogen from renewable electricity. Since 2008 the Hychico pilot project in the Argentine Patagonia has been producing around 52 t $H_2$/yr from wind power, using two alkaline water electrolysers with a joint capacity of 0.55 MW. The hydrogen is

[1] This excludes the approximately 2.2 Mt $CO_2$/yr of concentrated $CO_2$ streams that are separated and utilised to manufacture urea. A large proportion of this embedded $CO_2$ is re-emitted in the agricultural sector when fertilisers containing urea are applied to soils.

mixed with natural gas for power generation using a 1.4 MW generation unit that can operate over a wide range of gas/hydrogen blends, including pure hydrogen. The Hychico project also has Latin America's only dedicated hydrogen pipeline system (2.3 km) and an underground storage facility.

Since 2011 the Ad Astra Rocket pilot in Costa Rica has been producing around 0.8 t $H_2$/yr from solar and wind power in the city of Liberia, using a 5 kW polymer electrolyte membrane (PEM) electrolyser. The hydrogen is used to power the first fuel cell bus in the region, as well as four fuel cell light-duty vehicles.

At 4 500 metres above sea level, the Cerro Pabellón microgrid pilot project in Chile's Atacama Desert has been using solar power to produce 10 t $H_2$/yr using a 50 kW PEM electrolyser. Operational since 2019, the project provides dispatchable renewable electricity to cover the needs of a microgrid serving a community of over 600 technicians working at a geothermal plant.

In addition to these three pilot projects, the pipeline of future projects at the time of writing includes more than 25 projects at various early stages of development.[2] Assuming that all these projects will be built with the announced capacity and that they will be supplied with low-carbon hydrogen, they represent an additional production capacity of over 2 Mt $H_2$/yr, or almost half of regional production in 2019.

[2] Annex 1 provides information on the low-carbon hydrogen project pipeline in the region.

# Potential demand for hydrogen in Latin America's clean energy transitions

Latin America is home to a large hydrogen industry that may now be on the verge of an unprecedented transformation, driven by ambitious GHG emission reduction goals and technological developments, and leveraging the region's abundant and competitive resources. The hydrogen industry would undergo this transformation on two fronts: the replacement of current hydrogen supply with low-carbon hydrogen production technologies, and the expansion of hydrogen use to new applications.

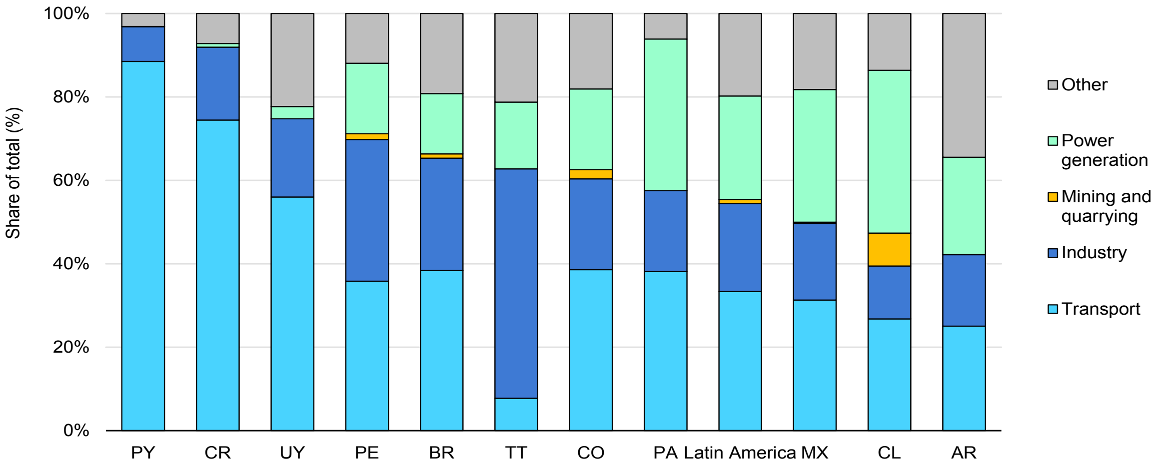
In this section we explore the potential evolution of hydrogen demand in Latin America to 2030. We make projections for key sectors using assumptions and analysis informed by IEA in-house expertise, consultations with government officials and discussions with energy experts from different institutions.

## Priority sectors for hydrogen deployment

Decarbonising Latin America's energy systems will require reducing emissions from transport and industry, which in 2018 accounted for around 35% and 23% of the region's total $CO_2$ emissions respectively, including $CO_2$ emissions from fuel combustion and processes in industry. Emissions from the transport sector are even more relevant in certain countries, including Costa Rica, Paraguay and Uruguay, where industrial energy demand is limited and where the power sector is almost fully decarbonised.

The sale of maritime fuels (bunkers) for international maritime transport is not included in the national emissions figures, but is responsible for significant emissions. Emissions from international seaborne transport were estimated at 2.51% of global anthropogenic $CO_2$ emissions in 2018. Almost a third of the region's bunker sales for international transport take place in Panama, the combustion of which leads to $CO_2$ emissions similar to the total for the country of Panama itself.

**Figure 7 $CO_2$ emissions by sector for selected countries, Latin America, 2019**






Notes: AR = Argentina; BR = Brazil; CL = Chile; CO = Colombia; CR = Costa Rica; MX = Mexico; PA = Panama; PE = Peru; PY = Paraguay; TT = Trinidad and Tobago; UY = Uruguay.
Transport, Mining and quarrying and Other refer to $CO_2$ emissions from fuel combustion only.
Industry refers to process emissions and emissions from fuel combustion, and excludes mining and quarrying. Process emissions refer to 2015.
Power generation refers to electricity and heat production.
Other includes energy sector own use and residential uses, among others.
Source: IEA $CO_2$ emissions from fuel combustion (2021), based on EDGAR database (version 4.3.2_FT2016).

In some countries, mining also accounts for a relevant share of emissions. In 2019 mining accounted for more than half of total exports from Chile and Peru by value, where it employed almost 400 000 workers, often in remote regions.[1] In Chile, diesel consumption in the mining sector corresponded to almost a quarter of the national total.

Decarbonising the transport and industrial sectors requires many different technologies. Certain long-distance transport modes and heavy industry sub-sectors currently rely on fossil fuels where direct substitution with electricity is impractical and/or expensive. Hydrogen technologies are one set of options that can contribute to emission reductions in these sub-sectors, provided the hydrogen is produced sustainably. The use of hydrogen in sectors where emissions are hard to abate relies on many technologies that are not mature yet, and action is needed in the short term to unlock their long-term potential for Latin America. Beyond decarbonising domestic energy uses, meeting global demand for low-carbon

[1] https://si3.bcentral.cl/estadisticas/principal1/excel/ccnn/trimestrales/excel.html and https://www.subrei.gob.cl/docs/default-source/estudios-y-documentos/reporte-trimestral/comercio-exterior-de-chile-anual-2019.pdf?sfvrsn=1eb0bb58_0. http://www.minem.gob.pe/minem/archivos/file/Mineria/PUBLICACIONES/VARIABLES/2020/BEMAGO2020.pdf. https://www.mch.cl/2019/03/07/empleo-en-sector-minero-crecio-4-en-2018/#.

goods, such as steel, chemicals and aviation and maritime transport fuels, could create opportunities for the region to capture export markets.

Governments in the region have a critical role to play in identifying the sectors that hold the greatest long-term potential in their country. Doing this early on – by including it in strategic documents and long-term energy planning – will allow countries to guide the development of hydrogen towards the most strategic opportunities for their unique situation, building on existing hydrogen infrastructure and value chains, where they exist.

Developing existing and new hydrogen uses could have significant infrastructure requirements to bring hydrogen to end users. For applications in industry and oil refining, sizeable low-carbon hydrogen demand could justify dedicated and potentially co-located production facilities. Other applications, such as maritime transport and mining, would be limited to ports and mining regions (e.g. northern Chile or southern Peru). Due to the scattered nature of demand, hydrogen applications in road transport would require significant investment in hydrogen refuelling and distribution infrastructure.

Applying the analysis that underpins this report, we have developed two cases for the potential evolution of hydrogen demand in key sectors in Latin America to 2030: a baseline case ("Baseline") and a case with accelerated deployment of low-carbon hydrogen technologies ("Accelerated").

# Defining the cases

The Baseline and Accelerated cases offer insights into the potential impacts on sectors that use or could use hydrogen of adopting different levels of ambition and policy support for hydrogen technologies. Our aim is to inform ongoing discussions about developing hydrogen uses in the region. The two cases are informed by, but different from, other IEA scenarios and should not be considered as predictions or forecasts. We did not model hydrogen supply, low-carbon or otherwise, in these cases, which refer to hydrogen demand only.

The Baseline case describes how demand for hydrogen could evolve considering energy- and climate-related policies already in place in the countries of the region, and an uptake on demonstrated technologies following commercialisation trends observed in other low-carbon energy technologies.

The Accelerated case reflects an optimistic vision for the deployment of hydrogen end-use technologies to 2030. It assumes the enactment of more ambitious energy- and climate-related policies and supporting mechanisms that could facilitate their implementation. This case describes trajectories that are compatible with the achievement of wider energy and climate targets, and represents an ambitious vision requiring more joint action from governments, industry and the financial sector to intensify activities across the whole value chain. The case assumes that the necessary infrastructure and techno-economic progress will materialise to bring these projects online in a useful and orderly manner.

The Baseline and Accelerated cases focus on existing uses of hydrogen in oil refining and industry, as well as emerging applications that could play a key role in decarbonising the region's energy consumption to 2030 and beyond. Due to limited data availability for certain uses, estimated hydrogen demand in 2030 does not include possible uses in the power sector, mining or buildings, which are also described qualitatively in this chapter. Moreover, the figures do not include demand for hydrogen exports from the region, which could become a reality by 2030.

**Table 1 Definition of Baseline and Accelerated cases**

| | Baseline | Accelerated |
|---|---|---|
| Conditions assumed | • Policies in place with specific measures enacted<br>• Private-sector commitments made publicly to deploy technologies where there have been explicit demonstration or pilot projects already undertaken<br>• Commercialisation of fuel cell electric vehicle technologies that are at the demonstration and early commercial stage, enabled by policy support and by cost reductions realised through economies of scale and technological learning<br>• Basic level of co-ordination between governments, academia, industry and financial sector | • Compatible with the direction outlined by the region's long-term energy and climate targets<br>• Rapid development of emerging end-use technologies in industry and transport, and rapid adoption in the region<br>• Establishment of support mechanisms to allow early deployment<br>• Achievement of technology deployment targets (to the extent possible by 2030)<br>• Rapid deployment of enabling infrastructure<br>• More ambitious joint action between governments, academia, industry and the financial sector |

# Hydrogen demand to 2030

**Figure 8 Hydrogen demand by application, Latin America, 2019-2030**

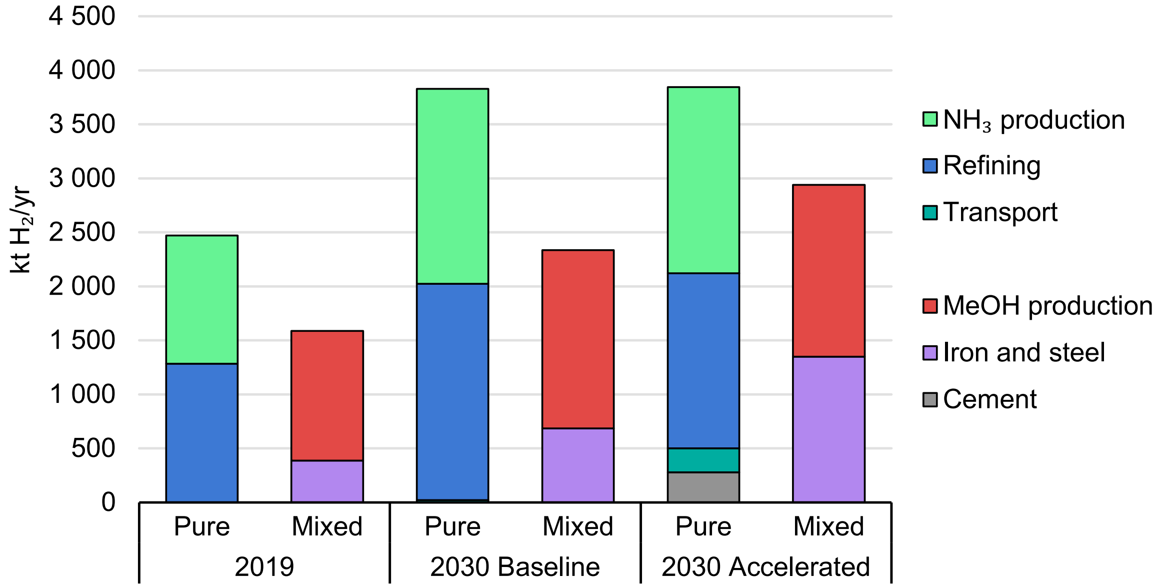
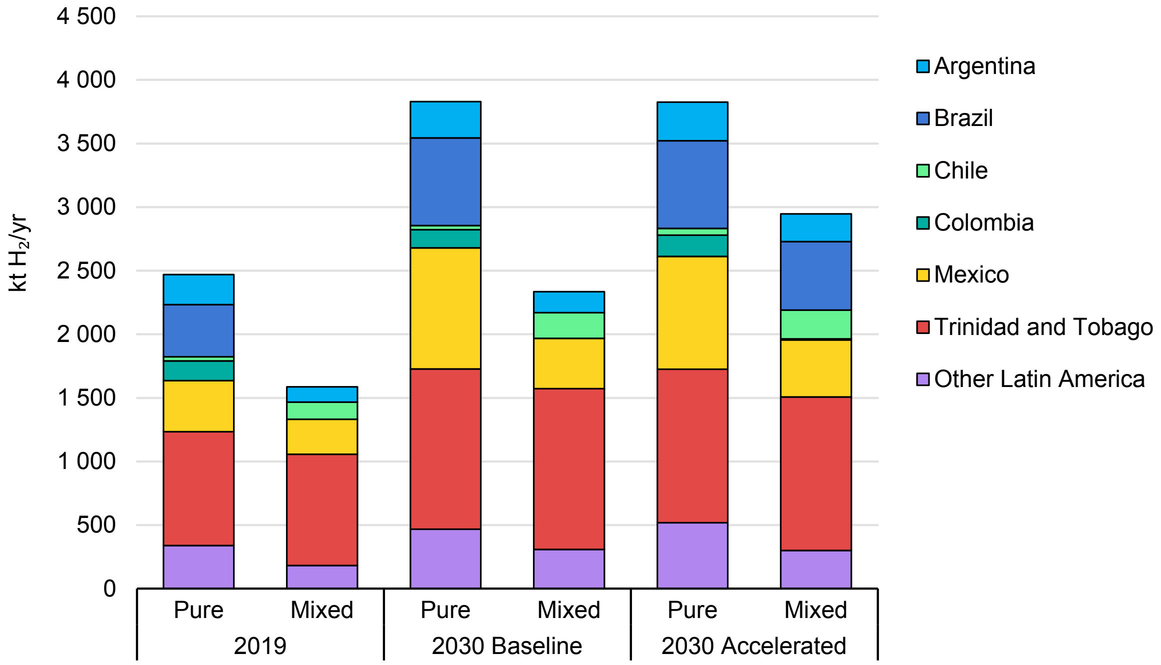





**Figure 9 Hydrogen demand by country, Latin America, 2019-2030**






Sources: IEA analysis based on IEA statistics, country surveys and data from the International Fertilizer Association, Wood Mackenzie, World Steel Association Steel Statistical Yearbook, Argentinian Petrochemical Institute Yearbook, ANP (Brazil) and Sistema de Información Energética (Mexico), among others.

Total hydrogen demand in Latin America could see significant growth to 2030, with most additional demand coming from existing uses in oil refining and industry. In both cases, economic growth is the largest driver of hydrogen demand, while environmental policies have a limited impact on demand for new applications. In the Accelerated case, a change in the distribution of total demand begins to take place by 2030, highlighting that the next decade could be critical to the adoption of hydrogen as an energy carrier beyond industry.

In the Baseline case, total demand increases by 52% to reach 6.2 Mt. Practically all the additional 2.1 Mt of hydrogen demand comes from existing uses in oil refining and industry, while demand for transport and new applications in industry remains very limited. Demand for ammonia production increases by more than 50%, as existing plants that were not operating in 2019 resume production in Brazil and Mexico by 2030.

In the Accelerated case, total demand increases by 67% to reach 6.8 Mt. New applications in industry and transport expand significantly to meet more ambitious energy and climate targets, while hydrogen demand for oil refining grows less than in the Baseline case. In both Baseline and Accelerated cases, demand for mixed hydrogen grows more than for pure hydrogen. In the Accelerated case, this is due to new uses of hydrogen in blast furnaces (especially in Brazil, where steel production via this route is highest). New applications in transport and industry are responsible for almost 18% of total hydrogen demand in 2030, thanks to the accelerated development and deployment of technologies that are not technologically mature as of 2021. Furthermore, this case assumes the rapid deployment of enabling infrastructure, such as hydrogen refuelling stations needed to support hydrogen uses in transport.

Despite the significant potential for hydrogen to decarbonise several sectors in the long term, new uses of hydrogen in the region are likely to remain modest to 2030 and existing uses will continue to dominate regional hydrogen demand.

## Hydrogen in the refining and industrial sectors

**Table 2 Location of key industrial and refining facilities, Latin America, 2019**

| | Countries |
|---|---|
| Oil refining | AR, BO, BR, CL, CO, EC, MX, PE, VE |
| Chemicals – ammonia | AR, BO, BR, CO, MX, PE, TT, VE |
| Chemicals – methanol | AR, CL, TT, VE |

| | Countries |
|---|---|
| Iron and steel – DRI | AR, MX, TT, VE |
| Iron and steel – Blast furnace | AR, BR, CL, CO, MX |
| Cement | All |

Notes: *Oil refining* includes countries with estimated hydrogen demand for oil refining over 10 kt $H_2$/yr in 2019.
AR = Argentina; BO = Bolivia; BR = Brazil; CL = Chile; CO = Colombia; CR = Costa Rica; EC = Ecuador; MX = Mexico; PA = Panama; PE = Peru; PY = Paraguay; TT = Trinidad and Tobago; UY = Uruguay; VE = Venezuela.
Sources: IEA analysis using data from World Steel Handbook and USGS.

## Oil refining

Hydrogen demand for oil refining grows by 3.4% per year to 2030 in the Baseline case and 1.5% in the Accelerated case. In the latter case, lower growth is linked with increased adoption of low-carbon mobility solutions (such as battery electric vehicles, fuel cell electric vehicles and biofuels) and higher fuel efficiency, among other factors.

While changes in the levels of activity are the main drivers for hydrogen demand in oil refineries, hydrogen requirements could also increase as the region moves towards more stringent sulphur content requirements in refined oil products, which could also have positive effects on local air quality and public health. The production of advanced biofuels (such as hydrotreated vegetable oils [HVO]) could also generate some additional demand for hydrogen by 2030, building on the region's world-leading biofuels sectors.

In Latin America, hydrogen used in refineries is predominantly produced from natural gas using steam methane reformers, but it is complemented with contributions from by-product gases at refineries (catalytic naphtha reformers). Substituting hydrogen produced from unabated fossil fuels with low-carbon hydrogen is an early opportunity to scale up low-carbon hydrogen production. This can be enabled by retrofitting existing plants with CCUS (depending on access to $CO_2$ transport and storage infrastructure) or by using electrolysers powered by renewable electricity.

## Ammonia and methanol production

Ammonia and methanol are almost exclusively produced using fossil fuels, apart from some electrolysis-based ammonia production in Peru. Trinidad and Tobago produces almost three-quarters of the region's ammonia and a third of its methanol, most of which is exported to markets outside the region.

Pure hydrogen demand for ammonia in the region increases by 52% and 45% by 2030 in the Baseline and Accelerated cases, respectively. Hydrogen demand for ammonia production in Brazil more than triples in both cases, as production from idled capacity restarts by 2030. In 2019 ammonia output stood at just 20% of the country's installed production capacity.

Agriculture is the main driver for ammonia demand in Latin America, where it is used as nitrogen fertiliser in the form of urea or ammonium salts. Global demand for grains and food is expected to continue growing to 2050 to support a growing population, despite technological improvements and increased agricultural efficiency. Lower demand growth in the Accelerated case can be linked to increased efficiency in fertiliser use, as well as a shift away from urea towards other nitrogen-based fertilisers that are easier to decarbonise.

Mixed hydrogen demand for methanol production increases by 38% and 33% by 2030 in the Baseline and Accelerated cases, respectively. Lower demand growth in the Accelerated case can be linked to lower demand for transport fuels, where methanol is used as a gasoline additive and for the production of biodiesel, which is tied to diesel demand via blending mandates.

## Iron and steel production

Hydrogen can substitute fossil fuels in the iron and steel sector – both in existing installations, where only a partial substitution of the fossil fuel input is generally possible, and in the longer term (post-2030) in 100% hydrogen-based facilities. In 1999 Trinidad and Tobago was home to the world's first large-scale plant employing an iron ore reduction process that uses pure hydrogen.

The two main methods of steel production from iron ore, blast furnace-basic oxygen furnace (BF-BOF) and direct reduced iron-electric arc furnace (DRI-EAF), are currently in use in Latin America. BF-BOF steelmaking is used in Argentina, Brazil, Chile, Colombia and Mexico and accounts for more than half of the region's crude steel production. The DRI-EAF steelmaking route is limited to Argentina, Mexico, Trinidad and Tobago and Venezuela, and accounts for around 14% of the region's total crude steel production, with the remaining production corresponding to secondary steel production from scrap.

Steel demand to 2030 grows less in the Accelerated case than in the Baseline case (40% vs 48%) due to accelerated improvement in material efficiency in construction and manufacturing, which reduces steel requirements in buildings, vehicles and appliances. In the Accelerated case, additional hydrogen demand comes from BF-BOF production, where a part of the coal used in existing facilities can be substituted with pure hydrogen, an application that has already been demonstrated in Germany. In DRI-EAF steelmaking, pure electrolytic hydrogen could replace part or all of the syngas produced from the natural gas steam reformer, resulting in a hydrogen-rich syngas. Hydrogen demand from the iron and steel sector accounts for 29% and 46% of total mixed hydrogen demand in the Baseline and Accelerated cases, respectively. Steelmaking using 100% hydrogen DRI-EAF is not expected to be demonstrated before the end of the decade, and is therefore not expected to be used in the region by 2030.

## High-temperature heat

Manufacturing processes require heat at various temperature levels. Electrification solutions (using heat pumps, electrical resistance heaters or electro-magnetic heating technologies) are, in general, more suitable for applications demanding low/medium-temperature heat or for small-scale applications requiring high temperatures. Some industrial applications requiring high-temperature heat, especially for large heated volumes, may be more suitable for hydrogen instead of direct electrification.

The cement industry is a major contributor to high-temperature heat requirements in industry. Cement production is an emissions-intensive process that takes place in practically all countries of the region, generally in smaller industrial facilities than those described for the chemical and iron and steel sectors. Around two-thirds of emissions from cement production stem from the calcination reaction that takes place during the production of clinker, which is the main active ingredient in cement. In the future, hydrogen could be used in combination with other fuels to provide a part of the thermal requirement for clinker production, replacing fossil fuels and helping decrease overall emissions in this heavy industry sector, alongside other fuels and technologies such as biomass, CCUS and direct electrification. In the Accelerated case, hydrogen demand for cement production accounts for 67% of total pure hydrogen demand in 2030 as a result of strong policy action to promote low-carbon cement production, compensating for part of the demand reductions in refining and ammonia production.

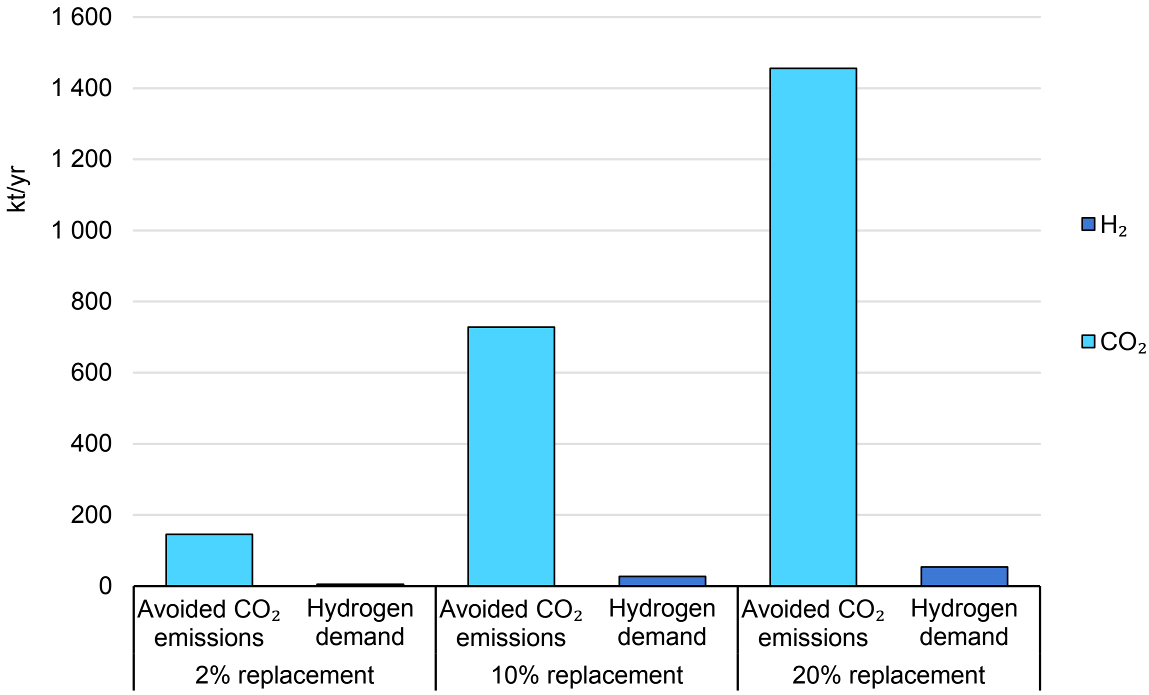
## Mining

Mining typically consumes electricity for stationary applications (such as shovels and processing equipment) and oil products (mainly diesel) for non-stationary applications, such as mining haul trucks to transport large volumes of minerals, as well as the overburden that is removed to access them. Copper mining alone was responsible for 79% of total diesel consumption in Latin American mining, as low ore grades and high strip ratios (the volume of overburden removed per tonne of ore mined) in open-pit mines require large fleets of mining haul trucks, with large tonnage and high utilisation rates. (The fleets amounted to between 1 200 and 1 500 trucks in Chile, at least 500 in Peru and 100 in Mexico, based on publicly available data for the largest copper mines in these countries.) Copper requirements could grow by 25% to 2030 to support the deployment of clean energy technologies, according to recent IEA analysis on the role of critical minerals in clean energy transitions. Haul requirements for copper mining could grow even faster due to the expected decline in ore grades in the region, which in Chile have deteriorated by 30% in the last 15 years.

Decarbonising energy consumption in mining will require many technologies, electrification being an option for many static applications, including the installation of conveyor belts to transport ores for processing or catenaries to power electric vehicles along defined and stable routes. Mining haul trucks could be good candidates for hydrogen-based solutions. Komatsu, one of the main suppliers of mining haul trucks, plans to launch hydrogen mining haul trucks by 2030. Anglo-American and Engie are due to start testing a prototype hydrogen-fuelled mining haul truck in South Africa during 2021, supported by a 3.5 MW electrolyser to produce low-carbon hydrogen on site.

Policy makers in Chile have identified non-stationary uses in mining as a key future demand sector for low-carbon hydrogen, based on the development of hybrid diesel/hydrogen mining trucks. In the large mines of northern Chile, hydrogen could be produced locally and competitively thanks to high-quality solar resources. Given current technological maturity levels, hydrogen uses in mining infrastructure are unlikely to become widespread by 2030 beyond a few demonstration projects, but they could have significant impacts on emissions in the medium and long term (depending on the diesel engine and fuel cell efficiencies considered).

**Figure 10 Avoided $CO_2$ emissions and low-carbon hydrogen demand for copper mining in Latin America, 2030**






Notes: Data refers to hydrogen use in mining haul trucks in the copper mining industry in Brazil, Chile, Mexico and Peru. Replacement percentage refers to substitution of diesel with hydrogen in energy terms. Assumes mining haul truck fuel cell efficiency of 43% and diesel engine efficiency of 14%, and zero-emissions hydrogen production.
Source: Chilean Carbon Neutrality Plan for the Energy Sector (2019).

Technological development in Chile may be accelerated by ambitious industry targets. Codelco, the world's largest copper producer, announced in 2020 plans to reduce emissions by 70% by 2030, with a focus on electrification measures and investigating hydrogen uses. Chile's economic development agency, CORFO, is supporting at least three R&D projects to develop hybrid diesel/hydrogen mining haul trucks in partnership with the private sector and academia.[2]

## Hydrogen in transport

Hydrogen applications in transport have attracted a lot of attention from policy makers in Latin America and could be key to reducing emissions alongside other sustainable mobility options. Energy use for transport in the region is dominated by oil products, which accounted for more than 85% of final energy demand in transport in 2018.

[2] HYDRA Project, ALSET Consortium, UTFSM Consortium.

## Road transport

Road transport accounts for almost 95% of total transport demand in Latin America. In 2019 the share of biofuels in road transport (almost 12%) was more than double the global average (4%). This is largely thanks to Brazil, which had the world's highest share of biofuels in road transport in 2019 (27%), the result of continuous policy effort to support liquid biofuels and the introduction of flex-fuel vehicles that can run on pure bioethanol as well as blends of gasoline and bioethanol. In Argentina, compressed natural gas (CNG) accounts for 12% of the total energy demand for road transport, supported by more than 2 000 CNG refuelling points and a fleet of more than 1.7 million vehicles, mostly light-duty vehicles (LDVs). In recent years, Argentina's use of CNG (and LNG) as a fuel for heavy-duty transport has accelerated through pilot projects and discussions about CNG corridors to support its use along the country's main routes. Low-carbon hydrogen blending in CNG, which could reach 20% using existing LDVs, would reduce emissions from CNG use, but could result in higher fuel prices for end users. As in many other parts of the world, battery electric vehicles (BEVs) are set to be a key technology to reduce emissions from the road transport sector. They will require significant investment in charging infrastructure and (low-carbon) power generation capacity. The governments of Chile, Colombia and Costa Rica have announced targets and ambitions for deploying electric mobility in the coming decades, with a focus on LDVs and urban buses.[3]

Fuel cell electric vehicles (FCEVs) could also play a role in road transport applications that may be less technologically suitable and/or economically competitive for BEVs, such as those requiring long driving ranges, high utilisation rates, high power levels, energy-dense fuels and short charging times. In Colombia, legal targets for the sale of zero-emissions urban buses (10% of sales in 2025 and 100% by 2035) include both BEVs and FCEVs. Technology improvements and cost reductions will ultimately determine the right combination of technologies to decarbonise transport in the region. The first FCEVs introduced in the region, a bus and four LDVs, have been circulating in Costa Rica since 2011, using hydrogen produced from renewable electricity and supported by Latin America's first hydrogen refuelling station. In Brazil, an FCEV bus prototype was developed locally with funds from the utility-funded R&D investment obligations programme of the power sector regulator, ANEEL.[4] In 2016 Mexico's National

[3] These ambitions and others are listed in the IEA's Global EV Policy Explorer https://www.iea.org/articles/global-ev-policy-explorer.

[4] https://diariodotransporte.com.br/2017/04/08/apos-cinco-anos-e-r-10-milhoes-onibus-a-hidrogenio-do-rio-esta-apto-a-operar-comercialmente/.

Institute of Electricity and Clean Energy (INEEL) developed and tested an FCEV prototype for a small utilitarian vehicle, in collaboration with academia.

The application of fuel cell electric technology in LDVs (both private and commercial) and buses is more mature than in heavy-duty vehicles, but its commercial adoption lags significantly behind BEVs. Fuel cell electric LDVs and buses could play an initial role in the deployment of hydrogen-based sustainable mobility technologies. The deployment of refuelling infrastructure and greater consumer awareness can contribute to the acceptability of this technology in the longer term. This initial (and limited) deployment could focus on vehicle fleets in the public and private sector, especially those running on predetermined routes, which can share a limited amount of (costly) hydrogen refuelling infrastructure, as ensuring high usage reduces its marginal cost. Beyond 2030 fuel cell electric heavy-duty vehicles may reach technological maturity and unlock possibilities for reducing emissions in a key sector for the region, especially long-distance heavy-duty transport, an essential transport mode for regional trade.

**Table 3 Stock and sales share of FCEVs in 2030 in the Baseline and Accelerated cases**

| FCEV category | 2030 Baseline | | 2030 Accelerated | |
|---|---|---|---|---|
| | Stock | Sales | Stock | Sales |
| Buses | 0.05% | 0.08% | 0.28% | 0.45% |
| Trucks | <0.01% | <0.01% | 0.27% | 0.78% |
| Cars | <0.01% | 0.02% | 0.02% | 0.06% |
| LCVs | 0.04% | 0.1% | 0.16% | 0.45% |

Notes: Estimations are based on current vehicle stocks in Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Panama, Paraguay, Trinidad and Tobago and Uruguay. Buses include urban, interurban and minibuses. Trucks include medium-duty and heavy-duty trucks. LCV = light commercial vehicle.

The Baseline case sees very limited deployment of hydrogen-based mobility technologies by 2030, with around 14 000 FCEVs, mainly cars, LCVs and buses, principally in Brazil, Chile and Colombia and requiring less than 15 kt $H_2$ per year, 3.6% of the estimated hydrogen demand for 2019. In the Accelerated case, uptake is much quicker thanks to ambitious targets from government, robust support measures and the rapid deployment of enabling infrastructure, particularly hydrogen refuelling stations. Total FCEV stocks reach around 60 000 and circulate in most countries of the region, supported by 800 to 1 700 hydrogen refuelling stations[5] and creating annual demand of over 150 kt of pure hydrogen by 2030. Even in this ambitious case, FCEVs represent less than 0.3% of total medium- and heavy-duty truck stocks and similarly less than 0.3% of all urban and inter-urban buses in the region. While hydrogen's contribution to transport sector decarbonisation remains modest to 2030, an early focus on developing regulation, standards and infrastructure for these new applications is crucial to prepare the ground for large-scale deployment after 2030. For this, Latin America should draw lessons not only from international best practices, but also from its own successful experiences in deploying biofuels and CNG. They highlight the need for sustained policy focus and the benefits of creating local and regional value chains to support the uptake of emerging fuel technologies.

**Hydrogen in freight transport: An opportunity for regional collaboration**

In Latin America, low population densities and limited railway infrastructure contribute to the dominance of road freight transport, which accounts for over 90% of total internal freight transport in Argentina, Chile and Uruguay and over 50% in Brazil, where railway transport is extensively used in the mining industry.

Road freight transport is also relevant for regional trade, particularly in Mexico, where it is the main mode for importing and exporting goods. It is also important in Central America, where vehicles often drive through several countries, and in the Southern Cone (Argentina, Brazil, Chile, Paraguay and Uruguay), where regional trade relies heavily on trucks driving long distances. In Argentina, Chile and Mexico, driving distances for freight trucks can reach more than 100 000 km/yr – more than double the global average.

While data on vehicle stocks involved in cross-border trade is unavailable in most countries, data for Brazil shows that over 50 000 foreign trucks were registered for circulation in the country, almost a third of them from Argentina.

Regional collaboration is essential for deploying sustainable mobility technologies in road freight transport, as transport routes often extend beyond national borders. Specific topics for regional collaboration include the development of standards, regulation and infrastructure to allow FCEVs to circulate in the region. Costa Rica's roadmap for hydrogen use in transport identifies road freight transport as a potential focus area for hydrogen development at the national and regional level, through the Central American Integration System (SICA). In South America, the

[5] Assuming an average nameplate (nominal) capacity of hydrogen refuelling station in the range of 400-1 000 kg $H_2$/day and a 20-65% utilisation factor. The nameplate capacity and utilisation factor at any one refuelling station relate to the vehicle type it is designed to supply (LDVs, buses or trucks, for example).

Mercosur working group on transport (SGT 5) works to harmonise standards and requirements for international transport in the region.

One example of international co-ordination on hydrogen infrastructure deployment is the first Hydrogen Infrastructure for Transport (HIT) project funded by the European Commission and which started in 2012. The goal of this project was to define optimum strategies to migrate hotspots of hydrogen production and consumption in densely populated areas to becoming local markets providing refuelling infrastructure to support long-distance transport along strategically selected corridors.

### Shipping and other transport modes

Beyond road transport, different technologies are being developed for hydrogen to replace fossil fuel use in shipping, aviation and rail transport (especially diesel passenger trains, which are not widespread in the region). Hydrogen and hydrogen-based fuels could be among the few viable clean energy technologies to reduce emissions associated with long-distance shipping and aviation, with the latter being a longer-term opportunity. These technologies could coexist with others such as electric ferries, which could be a more convenient option for short distances, and small electric ships that can travel long distances. Prototypes of ships using ammonia and hydrogen are currently being developed in other regions: small hydrogen-fuelled coastal ships could become available by 2023, while ammonia-fuelled vessels could become available as early as 2024. In Mexico, the P4G – Getting to Zero Coalition Partnership was established in 2020 to identify opportunities to promote sustainable shipping in the country, focusing on low-carbon fuels, vessels and port infrastructure.

The demand for hydrogen and ammonia fuels in shipping in 2030 stays below 10 kt in the Baseline case and grows to almost 50 kt in the Accelerated case. In both cases, a large share of the demand for hydrogen and ammonia fuels in shipping is concentrated in Panama, which accounted for 2% of global bunker sales for international maritime transport in 2018, reflecting the country's ongoing relevance in global maritime trade. The Panamanian government has recently outlined its ambition to position the country as a regional distribution hub for hydrogen, capitalising on its strategic location and existing port infrastructure. Additional small-scale opportunities may exist in small river barges, which often transport goods and passengers across long distances, including in the Amazon regions of Brazil, Colombia and Peru, where small vessels often travel long distances between towns to service sparsely populated areas.

## Hydrogen in the power sector

Two main trends are expected to reshape the Latin American power sector in the coming decades: the integration of increasing shares of variable renewable energy, and changes to climatic patterns influencing hydropower availability. These will result in greater flexibility requirements, particularly to meet seasonal and inter-annual variations. Hydropower provides a high share of Latin America's electricity at more than 45% of total generation and over 60% in Brazil, Colombia, Costa Rica, Ecuador and Paraguay (where it is practically 100%). Latin America's hydropower could be subject to increasing variability in water availability as a consequence of extreme weather events and greater variation in seasonal water flows. Hydrogen-based storage and power generation (using fuel cells with an inverter or turbines) could be one of the technologies needed to provide flexibility and store energy when other low-carbon sources of electricity are not available. By providing large-scale seasonal storage, hydrogen and hydrogen-based fuels could be better options than battery energy storage systems. Hydrogen's long-term storage capabilities can also contribute to systems where hydropower is not as dominant, but which have large shares of other renewable sources with a seasonal generation profile such as solar PV.

Hydrogen and hydrogen-based fuels can also enable further renewable energy integration. Several countries in Latin America have an electricity mix with a variable renewable share of more than 10% (mainly solar PV and onshore wind), with Uruguay reaching 32% in 2019. Combining hydrogen production, storage and power generation could provide demand-side flexibility for the grid (interruptible loads), seasonal and inter-annual storage and flexible power generation. This would contribute to grid balancing and complement other technologies, such as batteries and backup generators. Stored hydrogen can be used to generate low-carbon electricity, and electrolytic hydrogen can be produced and stored at times of energy surplus when renewable electricity would otherwise be curtailed, either due to excess supply in the system or to local network constraints.

Hydrogen applications are starting to appear in the long-term power sector planning of some Latin American countries. Mexico's 2021-2035 Programme for the Development of the National Electric System (PRODESEN) sees limited deployment of hydrogen-fuelled turbines after 2030. Chile's 2020 long-term energy planning process and Colombia's National Energy Plan 2020-2050 also consider hydrogen uses in the power sector in their most climate-ambitious scenarios.

In the short term specific opportunities for hydrogen may exist in islands and isolated systems, particularly those that depend on liquid fuels for power generation, which results in very high marginal prices. These systems can have a levelised cost of electricity higher than USD 200/MWh and suffer from reliability issues. Renewable electricity coupled with hybrid hydrogen–battery storage systems could be the most cost-effective solution, provided good quality renewables are available. Three projects to provide isolated communities with stable and low-carbon electricity are in the advanced stages of planning in Barbados, French Guiana and Mexico, for a total of 66 MW of PEM electrolysis and 15 MW of PEM fuel cell capacity. Barbados has an ambitious target of 100% renewables in power generation by 2030 and could be at the forefront of the challenging task to decarbonise island power supplies.

At an even smaller scale, low-carbon hydrogen could also replace liquid fuels for small back-up power generators, which are prevalent in large commercial and residential buildings in the region.

In any case, the extent to which low-carbon hydrogen is deployed in the Latin American power sector could vary greatly, depending both on local conditions and on the development of related value chains. Different factors influence low-carbon hydrogen deployment, such as local hydrogen storage capacity, the geographic match between the best supply resources and demand, taxation and regulation, and the ability to retrofit and use existing generation facilities with hydrogen-rich fuels in a cost-competitive way. Moreover, the development of hydrogen supply chains for other end uses, such as industry and transport, may have an impact on production costs that influences the adoption of low-carbon hydrogen in Latin America's power sector.

## Hydrogen in buildings

Hydrogen can be delivered to buildings in two ways: blending hydrogen in existing gas networks, and using pure hydrogen in dedicated infrastructure. The latter is a longer-term (post-2030) opportunity than the former. A mandatory blending rate for low-carbon gases (including hydrogen and biomethane) in the gas network could be a transitional strategy. It would encourage low-carbon hydrogen production by artificially creating demand and use existing gas grids until dedicated hydrogen infrastructure is developed. Hydrogen use in buildings should be subject to high standards of safety to ensure consumer protection and acceptability. As low-carbon hydrogen is currently more expensive than natural gas in most countries, additional measures would be needed to avoid the negative impact of higher utility bills on end users.

The hydrogen blending tolerance of the network and all the end-use equipment downstream from the injection point varies greatly, and the network operator needs to conduct detailed technical assessment to identify areas of the network with higher tolerance and therefore better suited to hydrogen blending.

Natural gas use in buildings is not widespread in Latin America, as space heating demand tends to be low and gas distribution networks are limited. The only notable exception is Argentina, where natural gas accounts for around 60% of residential energy demand, with more than 50% of it used for space heating (especially in cold regions), and is subject to strong seasonality.

Further energy efficiency improvements in end-use technologies and the electrification of heat will be central to reducing emissions from buildings, with heat pumps reaching higher efficiency levels than other low-carbon alternatives. For instance, more than five times more green electricity is typically required to heat a household with electrolytic hydrogen than with a heat pump. However, pure hydrogen could be a valuable solution in high density areas, particularly where buildings are old and where greater flexibility from the electricity grid is needed.

# Hydrogen production in Latin America: Options for scaling up

## Low-carbon hydrogen from existing fossil fuel infrastructure

Current hydrogen production routes result in considerable emissions in Latin America. Retrofitting existing production units with facilities for CCUS could help to reduce emissions while leveraging existing industrial facilities and infrastructure.

A short-term opportunity to decarbonise existing hydrogen production could exist in oil refineries that use SMR to produce hydrogen, and in ammonia plants without concurrent production of urea. In 2019 these applications accounted for 2 200 kt of pure hydrogen demand and 19.5 Mt of $CO_2$ emissions. Depending on process characteristics, many of these emissions are released in high-concentration streams that could translate into low carbon capture costs. Ammonia plants in the region tend to have higher hydrogen requirements than oil refineries, which could enable savings from economies of scale, especially for CCUS, provided this option is technically viable in the location of the plants.

Retrofitting existing SMR plants with CCUS relies on technologies that are currently in the early deployment phase, but opportunities are mainly limited by the availability (and cost) of suitable $CO_2$ transport and storage facilities. Despite these challenges, retrofitting large ammonia plants with CCUS could be a near-term opportunity to significantly ramp up low-carbon hydrogen production in the region while leveraging existing infrastructure to export low-carbon ammonia. However, this opportunity crucially depends on global demand for low-carbon ammonia, as well as certification processes. With hydrogen demand for oil refining and ammonia production set to increase in the next decade, projects for new fossil fuel-based production capacity could include CCUS from initial designs or consider applying emerging technologies, depending on their maturity.[1]

[1] Including auto-thermal reformers, in the early deployment phase, and methane pyrolysis, in the prototype phase.

### Using bioenergy to produce hydrogen

The development of biogas and biomethane can support the hydrogen scaling-up process in the region and play an important role in Latin America's clean energy transitions. The most common production route is the anaerobic digestion of urban or rural waste to produce biogas that is later upgraded to biomethane – which is almost identical in composition to natural gas. The region has large potential to produce biomethane from different sources. Brazil's biomethane potential alone could represent 12% of the global total.

Biogas can play a role in decarbonising existing hydrogen production in two ways, especially in locations that may not have access to other competitive low-carbon hydrogen sources.

First, biomethane can be used in existing natural gas-based hydrogen production since it is interchangeable with natural gas, relies on commercially available technologies and leads to lower fossil $CO_2$ and methane emissions. Biomethane blending could reduce emissions further, even reaching negative emissions depending on the blending rate, when combined with CCUS. Moreover, hydrogen injection into anaerobic digesters can increase biomethane production through biological hydrogen methanation.

Second, biomass can be gasified to produce a syngas, which offers another low-carbon hydrogen production route. Different sources of biomass and residues can be used to produce syngas. Although this pathway could be closer to technological maturity than other technologies, it is currently limited to a few small-scale R&D applications and needs further development to reach commercial availability.

The use of liquid biofuels for hydrogen production is also being studied in the region. In Argentina, a solid-oxide fuel cell is being tested for electricity generation using hydrogen from bioethanol reforming.

A key advantage of using biogas is the possibility to deliver benefits beyond reducing emissions. Anaerobic digestion plants allow for nutrient recovery (with the production of low-carbon fertilisers), developing local supply chains, often in rural areas, promoting a circular economy and mitigating local pollution. Recent life-cycle analyses for Brazil have even suggested the potential to use these technologies, in combination with CCUS, to achieve negative emissions.

Biomethane and hydrogen use many technologies and services from the natural gas supply chain, and can both leverage existing gas infrastructure and demand to accelerate their deployment. These synergies should be considered when developing policies, regulation and support measures to promote one or both of them as low-carbon gases.

# Opportunities for CCUS in Latin America

CCUS technologies are critical for putting energy systems around the world on a sustainable path. CCUS can play a strategic role as a cost-effective pathway for low-carbon hydrogen production (itself a solution for the most challenging emissions in sectors such as heavy industry), for removing carbon from the atmosphere, and for tackling emissions from existing energy assets. Interest in CCUS is expanding in Latin America and globally, in parallel with growing interest in low-carbon hydrogen. The renewed momentum for CCUS, identified by the IEA in 2020, has been driven by strengthened climate commitments from governments and industry, including ambitious net-zero emissions targets.

CCUS developments in Latin America highlight both the opportunity that exists and the need for increased support from governments, industry and financial stakeholders to allow these technologies to contribute to regional decarbonisation. Many economies in the region have limited experience of and preparedness for CCUS, but there have been important developments. Mexico, with the support of the World Bank, has undertaken feasibility studies for pilot projects applying CCUS to gas-fired power generation, Trinidad and Tobago has experience in $CO_2$ injection for enhanced oil recovery (EOR) and the Haru Oni project in Chile is set to rely on combining $CO_2$ from direct air capture and electrolytic hydrogen to produce synthetic methanol and gasoline. Countries with large biofuels production may have opportunities to use associated $CO_2$ emissions to produce liquid fuels using biogenic carbon and (low-carbon) hydrogen.

Brazil hosts the only commercial CCUS facility in Latin America: the Petrobras Santos Basin Pre-Salt Oil Field CCS project. This is the only offshore EOR project in operation in the world. Since 2013 $CO_2$ has been separated from gas extracted with oil from two ultra-deepwater fields 300 km off the coast of Rio de Janeiro. Around 3 Mt $CO_2$ a year are reinjected in the nearby pre-salt reservoir for EOR some 5-7 km below sea level. While this project reduces energy sector emissions, it does not capture emissions linked to the combustion of fossil fuels, which would be the main way in which CCUS could play a role in decarbonisation.

# Mapping emissions clusters

Regional approaches to CCUS deployment, including targeting industrial hubs with shared $CO_2$ transport and storage infrastructure, could support economies of scale and accelerate uptake of CCUS in Latin America. Industrial clusters at ports and industrial centres in Latin America hold potential as $CO_2$ capture hubs that could access offshore $CO_2$ storage resources. Many of the industrial stakeholders that are already at advanced stages of developing hub-based CCUS projects in

Europe (including Norway's Longship project, the Netherlands' Porthos project and the UK Net Zero Teesside project) are active in these industrial clusters. Latin America could benefit from building on their experience to develop this technology in the region. In 2021 three South American ports (Bahía Blanca in Argentina, Pecém in Brazil and Mejillones in Chile) joined the Global Hydrogen Ports Coalition of the Clean Energy Ministerial's Hydrogen Initiative.

### CCUS potential in selected countries in Latin America

| Region | Emissions from $H_2$ production in 2019 (main end uses) | Readiness for CCUS* | Selected opportunities |
|---|---|---|---|
| Trinidad and Tobago | 16 Mt $CO_2$/yr (chemicals, DRI) | Medium: considerable experience in $CO_2$ injection for EOR; concentrated $CO_2$ sources in proximity to potential $CO_2$ storage sites | Potential hub at Point Lisas Industrial Estate; storage associated with EOR |
| Mexico | 6 Mt $CO_2$/yr (oil refining, DRI, chemicals) | Medium: initiated pilot programmes with support from the World Bank, but limited experience | Planned refineries and modernisations could include $CO_2$ capture from hydrogen and power production |
| Brazil | 4 Mt $CO_2$/yr (oil refining, chemicals) | High: operating large-scale CCUS project | Industrial clusters in the states of Rio de Janeiro, Pernambuco and Ceará |
| Argentina | 3 Mt $CO_2$/yr (chemicals, oil refining, DRI) | Low–medium: CCS Atlas for Argentina in preparation | Industrial clusters at Port of Bahía Blanca and Port of Campana-Zárate |
| Chile | 2 Mt $CO_2$/yr (chemicals, oil refining) | Low: e-fuels project in development | Potential hub near methanol production facilities in Cabo Negro, Magallanes |
| Colombia | 1 Mt $CO_2$/yr (oil refining, chemicals) | Low: limited experience/initiatives | Industrial cluster at Port of Cartagena |

* High = potential for large-scale and near-term (less than 5 years) CCUS deployment because of available storage capacity (not necessarily connected to infrastructure) and existing experience in storage operations relating to CCUS; Medium = potential for CCS deployment in the medium term (within 5 to 10 years) due to available storage capacity and limited experience in storage operations relating to CCUS; Low = limited readiness for large-scale deployment of CCUS (more than 10 years in the future) and little or no experience in storage operations relating to CCUS.

### CCUS development and potential in Trinidad and Tobago

Trinidad and Tobago has considerable opportunity for CCUS given its experience in $CO_2$ injection for EOR, and a large petrochemical sector with concentrated waste $CO_2$ streams that can offer relatively low-cost capture opportunities. While capture projects are currently limited to a pilot project injecting between 10 and 20 tonnes per day into an onshore oil and gas field, the country has been involved in $CO_2$ EOR in some of its operations since initial testing in 1972. The country is one of the world's largest exporters of ammonia and methanol, the production of which generates in the order of 15 Mt $CO_2$ per year from more than 10 plants. Many of these facilities are clustered in the Point Lisas Industrial Estate – and could form the basis for a potential $CO_2$ capture hub, transporting it to nearby oil and gas fields for permanent storage offshore.

A 2012 regulatory review found that existing legal and regulatory frameworks for the oil and gas sector, with some additional regulatory approval processes, could be used to permit CCUS projects. The $CO_2$ Emission Reduction Mobilization (CERM) project, launched in 2017, has brought together various key stakeholders to advance CCUS in the country. In February 2021 the Ministry of Energy and Energy Industries established the Carbon Capture and $CO_2$ Enhanced Oil Recovery Steering Committee with a mandate to manage the implementation of a large-scale $CO_2$ EOR projects. Two local universities have also jointly proposed to develop a National Carbon Dioxide Storage Atlas starting in 2021, to be funded by the government and completed in two years. The country is currently assessing options to implement carbon pricing, which could be a valuable incentive for CCUS.

# Low-carbon hydrogen from electrolysis

## Opportunities for initial deployment

Water electrolysis, the electrochemical process in which water molecules are split into hydrogen and oxygen by applying an electrical current, is an additional low-carbon route to producing hydrogen, provided the electricity used is itself low-carbon. While electrolysers are a well-known and long-used technology in a variety of industrial sectors, scaling up their deployment to meet energy and climate objectives is likely to require cost reductions and improvements in efficiency and other technical characteristics.

The use of water electrolysis technologies remains very limited in Latin America, accounting for less than 0.3% of total hydrogen production in 2019. The largest electrolyser in the region is a 25 MW alkaline water unit used for ammonium nitrate production in Peru since 1965. Several water electrolysis technologies are currently being developed and scaled up, including alkaline electrolysis, polymer electrolyte membrane and solid oxide electrolysis cells, in order of decreasing technological maturity.[2] A few electrolysers are already in operation in Latin America, but large-scale deployment has yet to be seen in the region.

[2] https://www.iea.org/articles/etp-clean-energy-technology-guide.

Similar to low-carbon production from fossil fuels, existing hydrogen demand could support an initial scale-up of electrolytic hydrogen from low-carbon electricity. SMR used to produce hydrogen for oil refining and for ammonia production without concurrent transformation into urea could be key opportunities to ramp up electrolytic hydrogen production by 2030, despite remaining technological challenges.

Electrolytic hydrogen could replace part of the SMR production, reducing natural gas needs and emissions, but only if it is produced using low-carbon electricity. Depending on certification procedures, this could result in hydrogen production patterns that follow the variability in wind and solar PV (less so if using hydro or nuclear, or a combination of low-carbon sources). In an initial phase, variable electrolytic hydrogen production could be blended using the flexibility of the SMR and the overall process. Beyond the flexibility limit (the maximum amount of pure hydrogen the process can absorb without requiring additional investment), blending electrolytic hydrogen would require investment in storage infrastructure to ensure continuous operation.

In the near term some Latin American countries could leverage their highly renewable generation mixes to support small-scale electrolytic hydrogen production and test new end-use technologies. In 2019 Costa Rica, Uruguay and Paraguay generated more than 98% of their electricity using renewables, while this share was over 70% in Brazil, Colombia and Ecuador. Occasional surpluses of low-carbon generation can be found at a system level (due to renewable overcapacity) or locally (due to grid constraints), which could support pilot projects and early deployment efforts, but will need to be complemented with additional renewable capacity (co-located or not) for larger hydrogen production levels.

**Hydrogen production costs**

Hydrogen production from unabated natural gas via SMR is currently the most economical and mature technology, making it the most prevalent supply route by far. While carbon pricing will help reduce the gap with lower-carbon routes, the levelised cost of hydrogen production (LCOH)[3] from key low-carbon technologies, such as SMR or auto-thermal reforming (ATR) plus CCUS, or water electrolysis, would also have to decrease considerably from current levels. They are currently

[3] The LCOH estimates how much it would cost to produce each kilogramme of hydrogen considering investment costs, operational costs and expected hydrogen production.

significantly more expensive than hydrogen from unabated fossil fuels. Several factors influence hydrogen production costs, including capital expenses for electrolysers and other equipment, capital costs and, most importantly, energy costs (electricity or fossil fuels). In 2020 energy was estimated to account for 45% of the total cost of SMR/ATR plus CCUS and 55-75% of water electrolysis. The non-electrolytic routes are also subject to additional costs for carbon capture and storage, as well as carbon pricing for non-captured emissions.

While the need for CCUS makes low-carbon hydrogen from fossil fuels more expensive than traditional emissions-intensive production, carbon pricing helps reduce that gap between the two. A carbon price of USD 60/t $CO_2$, similar to levels reached in the EU emissions trading system (ETS) in May 2021, would have made production with CCUS practically competitive against unabated production in 2020. Certification schemes and the creation of demand for low-carbon hydrogen and derived products could help bridge some of the remaining price gap. For hydrogen production with variable renewables, locations with high-quality wind and solar PV resources[4] could offer the lowest power supply costs and longest hours of operation.

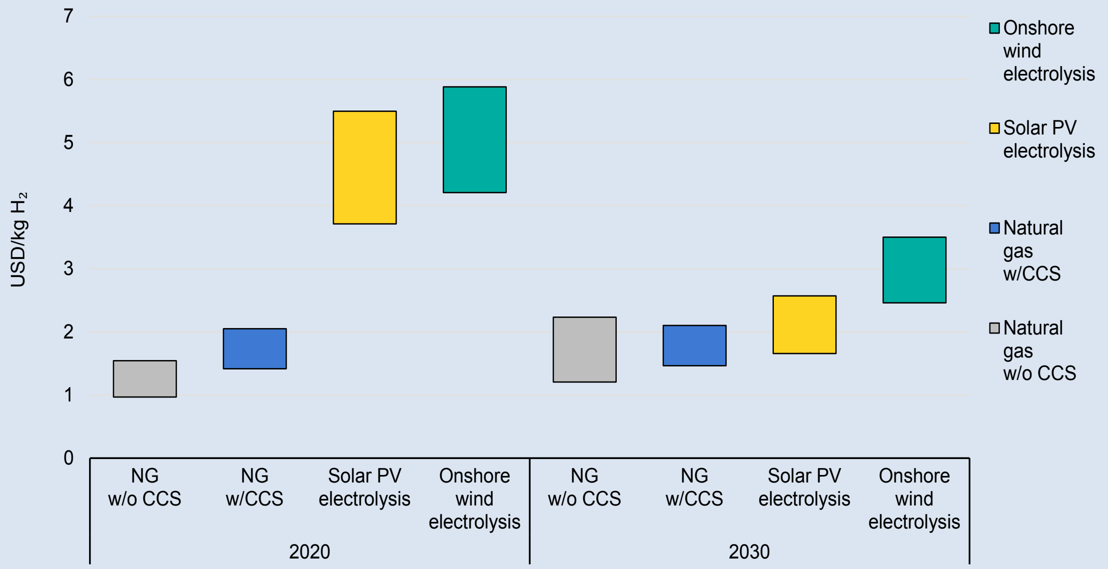
Although water requirements for hydrogen production are limited, the supply of water for projects in areas with high levels of water stress, such as the Atacama Desert, may have to rely on technologies such as water desalination. Although this would lead to higher water supply costs, its impact on total hydrogen costs is minor.

Ultimately, low-carbon hydrogen production costs from any technology will be determined by energy prices, either fossil fuels or low-carbon electricity, with CCUS costs (where relevant), capital costs and carbon pricing effects having a relatively minor contribution. Production with SMR/ATR plus CCUS is competitive against water electrolysis with variable renewables today in many locations, especially in countries with access to low-cost gas supplies. However, costs are expected to fall more rapidly in the water electrolysis route to 2030, as wind and solar PV prices continue to fall and the cost of electrolysers decreases from the scaling up of manufacturing capacity, benefitting from economies of scale and learning effects.

Based on data from the latest large-scale renewable energy auctions in each country, using global values for other parameters, we have estimated a range for LCOH from renewable water electrolysis by 2030.

[4] Locations where high solar irradiance and average wind speed translate to high capacity factors for solar PV and onshore wind projects, respectively.

**LCOH for selected technologies in Latin America, 2020-2030**






Notes: NG w/o CCS = natural gas-based hydrogen production without CCS; NG w/CCS = natural gas-based hydrogen production with CCS.

Assumptions: discount rate = 6%; system lifetime = 25-30 years; natural gas price = USD 3-7/MBtu (2020 and 2030); solar PV electricity cost = USD 27-43/MWh (2020) and USD 19-30/MWh (2030); onshore wind electricity cost = USD 40-57/MWh (2020) and USD 36-52/MWh (2030); $CO_2$ price = USD 0-10/t $CO_2$ (2020) and USD 15-90/t $CO_2$ (2030).

NG w/o CCS: CAPEX = USD 910/kW $H_2$; OPEX = 4.7% of CAPEX; LHV efficiency = 76%; load factor = 95%.

NG w/CCS: CAPEX = USD 1 474/kW $H_2$ (2020) and USD 1 459/kW $H_2$ (2030); OPEX = 4% of CAPEX; LHV efficiency = 69%; load factor = 95%; capture rate = 90%.

Electrolysis: CAPEX = USD 1 071-1 477/ $kW_e$ (2020) and USD 298-436/$kW_e$ (2030); OPEX = 0-3% of CAPEX; LHV efficiency = 65% (2020) and 69% (2030); solar PV load factor = 20% (2020) and 32% (2030); onshore wind load factor = 35% (2020) and 50% (2030).

## Scaling up electrolytic hydrogen production

In the next decade Latin America will need to take steps to decarbonise current production for existing uses and to ensure that new sources of demand are supplied by low-carbon hydrogen only. Additional demand for low-carbon hydrogen may come from export markets outside the region in the medium and long term. Latin American producers could access these markets once they have developed competitive low-carbon hydrogen production (to supply domestic demand in a first phase), implemented internationally recognised certification processes, and are able to ramp up low-carbon hydrogen production.

By 2030 the first hydrogen trade routes could be established, with Europe and Asia being two potential destinations for Latin America’s low-carbon hydrogen.

IEA analysis shows that north-western Europe may need to import 200-1 000 kt $H_2$/yr by 2030.[5] Japan's Basic Hydrogen Strategy estimates that the country will require around 300 kt/yr of hydrogen imports by 2030.[6] Latin America could face strong competition from other regions looking to supply these markets, including North Africa, the Middle East, Eurasia and Australia.

Hydrogen production from water electrolysis using low-carbon electricity could become increasingly attractive compared to other low-carbon production routes as renewable generation technologies and electrolysers become more affordable and certification requirements evolve, potentially favouring zero-emissions hydrogen over other low-carbon alternatives. These technologies could play a major role in meeting a growing share of low-carbon hydrogen demand in the long term.

Scaling up low-carbon hydrogen production will require significant investment in new renewable (or low-carbon) power generation capacity in almost every country, especially to ensure the use of this clean electricity to power electrolysers does not lead to additional emissions elsewhere in the system. This new generation capacity could be co-located with hydrogen production, depending on costs and, potentially, certification requirements. For water electrolysis facilities without co-located power generation, additional investment in transmission infrastructure could be necessary to ensure low-carbon power reaches the electrolysers, in addition to the significant transmission infrastructure already needed to support the ongoing deployment of variable renewables.

Additional investment in infrastructure will be needed to ensure that this low-carbon hydrogen reaches end users, such as hydrogen storage and overland and seaborne transport. Many options rely on technologies that are not mature or currently available at the right scale. Domestic applications would typically require hydrogen, whereas importing countries may require ammonia, as the technology to transport it is mature. Current ammonia producers in the region could leverage existing production and export facilities (mainly in Trinidad and Tobago), while other countries may require new facilities.

Transport infrastructure requirements in particular will increase as hydrogen use expands to new sectors. Demand could initially grow in so-called "hydrogen valleys", with one or more uses of hydrogen concentrated in an industrial hub, a port, city or region, requiring limited development of infrastructure over short distances (something that already exists in some parts of the world, such as

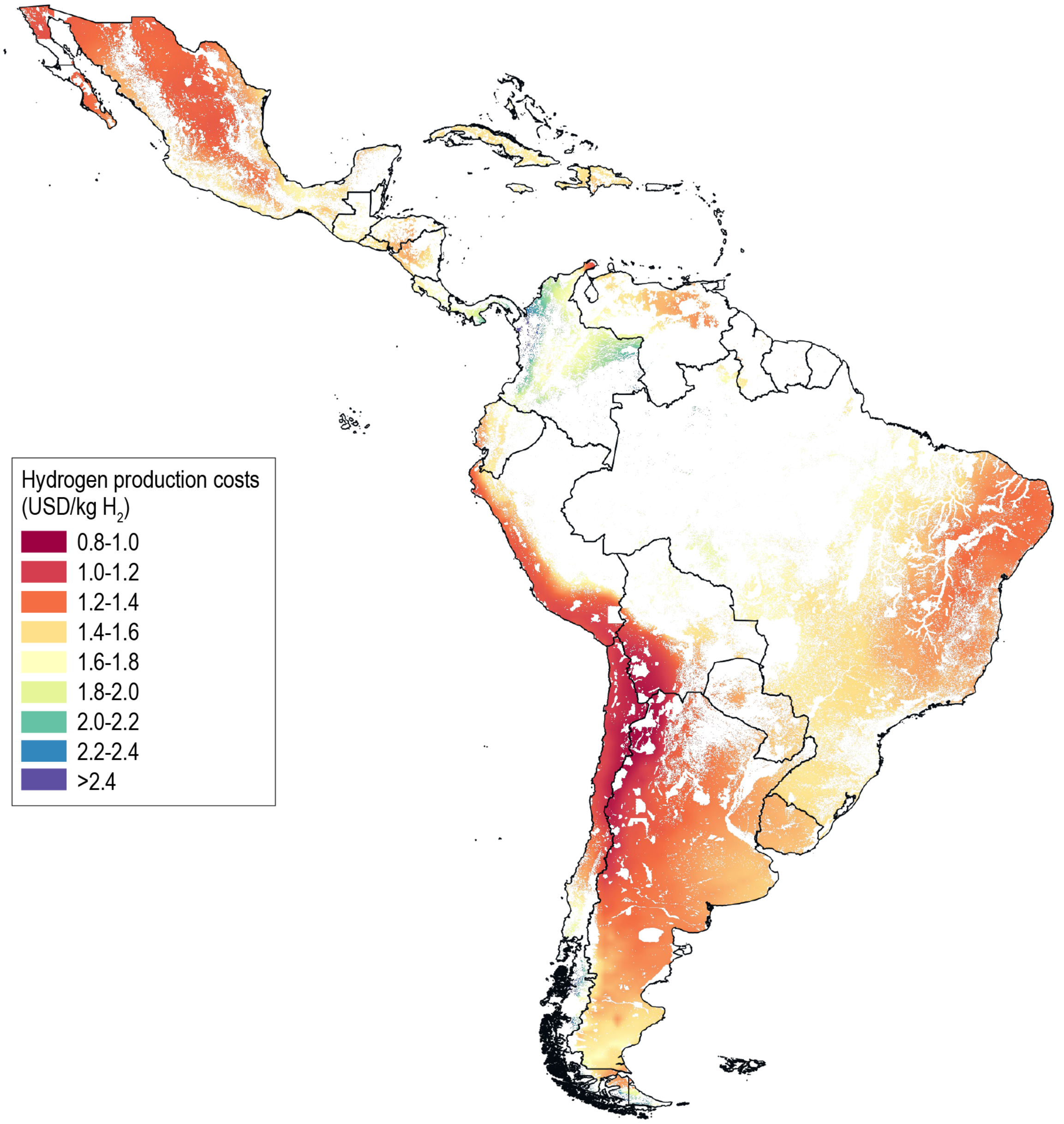
[5] https://www.iea.org/reports/hydrogen-in-north-western-europe.
[6] https://www.meti.go.jp/english/press/2017/1226_003.html.

north-western Europe and in the Gulf of Mexico). In the longer term, as hydrogen penetrates sectors with more scattered demand (such as road transport and buildings), larger hydrogen transport networks would become necessary, including across national borders. This process could be inspired by developments in other regions, such as the European Union, where the association of gas transmission system operators is developing the European Hydrogen Backbone Initiative to repurpose a large part of the region's gas network to transport pure hydrogen. Repurposing existing natural gas transmission grids to handle pure hydrogen could be up to 85-90% cheaper than building new ones. In Latin America, some gas transmission pipelines are currently underutilised and could in the long term be attractive for repurposing, such as the transmission pipelines between the far south and far north of Chile and Argentina, two prime areas for low-carbon hydrogen production.

Thanks to its abundant, high-quality and often complementary renewable resources, Latin America has the potential to produce large amounts of low-cost hydrogen from renewable electricity in the long term (2050). While many parts of the region could see competitive prices in this time horizon, the lowest production costs may be located in southern Patagonia (Argentina and Chile) and the Atacama region (Argentina, Bolivia, Chile and Peru), as well as north-western Mexico and north-eastern Brazil, among many others. These regions tend to be distant from current hydrogen demand hubs (such as industrial clusters), increasing the delivery infrastructure needed for scaling up production. In the long term, Latin America could have a land area of over 800 000 $km^2$ in which the LCOH via electrolysis is under USD 1/kg $H_2$ using a hybrid energy supply.[7]

[7] Protected areas, lakes, rivers and very steep zones are excluded from the calculation.

**Figure 11 LCOH via electrolysis powered by hybrid solar PV and onshore wind, Latin America, 2050**






Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Assumptions: Electrolyser CAPEX = USD 232-341/kW (onshore wind and solar PV); solar PV CAPEX = USD 325/kW; onshore wind CAPEX = USD 1 200/kW; electrolyser LHV efficiency = 74%; electrolyser OPEX = 3% of CAPEX; system lifetime = 33 years; discount rate = 6%.

Administrative areas (boundaries) based on: GADM, version 1.0, https://www.diva-gis.org/gdata.

Weather datasets: Wind data: Copernicus Climate Change Service (2020), ERA5 hourly data on single levels from 1970 to present, https://doi.org/10.24381/cds.adbb2d47, European Centre for Medium-Range Weather Forecasts. Solar PV: renewables.ninja, www.renewables.ninja.

Exclusion zones based on: ESA and UCL (2011), *GLOBCOVER 2009: Products description and validation*; USGS (1996), *Global 30 Arc-Second Elevation (GTOPO30)*; Global Lakes and Wetlands Database (GLWD): Lehner and Döll (2004), "Development and validation of a global database of lakes, reservoirs and wetlands", *Journal of Hydrology*, Vol. 296, Issues 1–4, 20 August 2004, pp. 1-22; FAO-UNESCO (2007), *The Digital Soil Map of the World*; WDPA (2020), December 2020 update of the WDPA and WD-OECM, https://www.protectedplanet.net/en/resources/december-2020-update-of-the-wdpa-and-wd-oecm.

# Policies for low-carbon hydrogen development in Latin America

To harness the full decarbonisation potential of hydrogen and the associated economic opportunities, Latin America will need to develop new low-carbon production facilities. But that will not be sufficient – it must also deploy emerging technologies to enable hydrogen's diverse end uses, as well as its transport, storage and international trade, a great challenge for policy makers in the region.

The preceding chapters have illustrated the strong case for low-carbon hydrogen in Latin America as well as the challenges and opportunities that exist in different sectors and locations, in the short and longer term. Reaping this potential will require policy makers to develop a tailored and carefully timed mix of policy and regulatory measures guided by strategic priorities.

## National strategies and roadmaps

National strategies and roadmaps are vital to orient the development of hydrogen towards the sectors and applications that are most relevant to each country, to identify opportunities in the short, medium and long term, and to pinpoint associated regulatory, infrastructure and skills requirements. They should also present a vision for the country's place in the future global hydrogen landscape, and consider developments in and capture complementarities with other countries in the region and beyond. National strategies can also be complemented by programmes at the subnational level, especially in federal countries like Argentina, Brazil and Mexico.

On the demand side, future end uses should be examined in light of their long-term emissions reduction potential, the availability and competitiveness of alternative decarbonisation options and the readiness levels of key end-use technologies. On the production side, relevant low-carbon production technologies should be selected in view of existing hydrogen production, the availability and competitiveness of renewable electricity or fossil fuels, and the availability of $CO_2$ transport and storage sites.

Policy makers should set ambitious but credible targets, based on detailed analysis, to mobilise stakeholders and attract investment. Targets should not focus on low-carbon hydrogen production only, but also on key demand-side metrics, such as annual demand in major industrial applications or stocks of FCEVs and hydrogen refuelling stations. Tracking progress will require the development of indicators, data collection processes and methodologies.

Governments need to ensure that these strategic documents align with the wider energy strategy and complement other clean energy policies and programmes. Given hydrogen's versatility, with applications across energy consumption sectors, the challenge will be to identify convergence and synergies between policies and programmes, and exploit them.

Existing hydrogen strategies, as well as ongoing studies and road-mapping processes in the region, are already contributing to further clarify these strategic priorities for each country and allowing policy makers to establish milestones for future deployment. The 2018 Costa Rican roadmap for hydrogen use in transport established a legal framework for public entities to start the development of hydrogen activities and identified the public vehicle fleet as an initial focus for development. In its 2020 strategy, Chile identified the primary opportunities to be the replacement of fossil-based hydrogen in the country's refineries and new applications in long-distance and heavy-duty transport. It set an ambitious target of 25 GW of electrolysis capacity to be installed or under development by 2030. Chile is currently the only non-EU country with a target for electrolysers.

To implement these roadmaps, policy makers will need hydrogen policies that mobilise the entire spectrum of measures, embracing regulatory, economic and fiscal/financial instruments, codes and standards, education and information campaigns, grants and subsidies to public-private partnerships and direct investment.

# Five areas for policy action

To provide a systematic overview of policy options and identify core recommendations, in this chapter we review five areas for hydrogen policy action: 1) immediate opportunities for low-carbon hydrogen; 2) investment and financing schemes; 3) R&D and skills development; 4) standards and certification; and 5) regional and international collaboration. Across these areas, the key to success will be to focus on lower-cost and nearer-term opportunities that build on existing policies, infrastructure, skills, geographical advantage and demand for hydrogen.

# Immediate opportunities for low-carbon hydrogen

## Decarbonising existing production

In Argentina, Brazil, Chile, Colombia, Trinidad and Tobago and Mexico, existing hydrogen demand can be the initial starting point for low-carbon hydrogen deployment. It can be a testing ground for new technologies to replace current production with low-carbon alternatives and unlock uses of hydrogen in new applications. This has already begun in Trinidad and Tobago, where the NewGen project is expected to start producing around 27 kt $H_2$/yr of hydrogen from water electrolysis by 2024, to replace part of the natural gas-based production in an ammonia plant.

Retrofitting existing hydrogen production facilities with CCUS represents an opportunity to reduce emissions and ramp up low-carbon hydrogen production in the near term, but depends on the availability and cost of suitable $CO_2$ transport and storage infrastructure. Building CCUS capacity in Latin America will require advances in: 1) identifying and developing $CO_2$ storage resources; 2) establishing legal and regulatory frameworks for CCUS activities; 3) implementing targeted policies for CCUS, including support for investment in $CO_2$ infrastructure; and 4) for some countries, accessing international finance to build capacity, unlock capital and encourage investment.

## Creating demand for new uses

In countries with no sizeable existing production of hydrogen, pilot projects will have to consider both hydrogen production and its use. Pilot projects could initially focus on the most easily achievable applications and those with long-term potential, such as vehicle fleets (e.g. the AdAstra pilot in Costa Rica), replacing ammonia imports (e.g. the HyEx project in Chile), or providing stable renewable electricity (e.g. the RenewStable project in Barbados). Additional opportunities could exist in small industrial vehicles, such as forklifts used in warehouses.

Due to the current costs of producing and using low-carbon hydrogen, government incentives are necessary for the initial phases of deployment of hydrogen production and supply technologies. They could include grants, fiscal exemptions and tax benefits among other support measures for early movers and pilot projects. To minimise fiscal impact, government support should target projects that focus on the most promising hydrogen uses for each country and the most easily achievable in the present as a basis for initial development. This is being done in competitive processes in Chile (Aceleradora H2V) and Uruguay (H2U). Deploying several pilots in sectors close to consumers can also help clear doubts that may exist around the security of hydrogen.

In the longer term, measures such as sectoral (and company-level) emissions reduction targets, carbon pricing and hydrogen certification or guarantees of origin schemes could provide economic signals for large-scale decarbonisation of current hydrogen uses.

**Carbon pricing in Latin America**

Carbon pricing is a valuable instrument in the policy toolkit to promote clean energy transitions and the more rapid deployment of low-carbon hydrogen. It could help guide investment decisions and support government objectives for a quicker rollout of low-carbon hydrogen by lowering costs compared to production from unabated fossil fuels.[1] There are different estimates of the value of carbon price that could trigger investment in low-carbon hydrogen. Some identify USD 50-145/t $CO_2$-eq as the carbon price range needed to spur investment in hydrogen from renewable energy, depending on the sector;[2] while others estimate a range of USD 67-110/t $CO_2$-eq to make low-carbon hydrogen with CCUS competitive versus production from unabated fossil fuels today.[3]

Certain Latin American countries have gradually taken up an increasing number of explicit carbon pricing initiatives, in the form of carbon taxes, an ETS, or a hybrid of the two. Since 2017 Argentina, Colombia and Chile have implemented a carbon tax, and Mexico has had a carbon tax since 2014 (including three more recent subnational carbon taxes) complemented by an ETS pilot launched in January 2020.[4] As of June 2021, Colombia and Brazil are also considering implementing an ETS, and Chile is reforming its carbon tax and proposing to implement in parallel a system to limit GHG emissions, which could be implemented as an ETS or as a tradable performance standard.[5]

All existing carbon pricing initiatives in Latin America cover hydrogen-related sectors, but pricing levels are too low to trigger investment in low-carbon hydrogen. The sectoral coverage of these carbon pricing instruments varies between countries. Industry and oil refineries are covered, with some exceptions, including

[1] https://www.iea.org/commentaries/the-clean-hydrogen-future-has-already-begun.
[2] https://www.bloomberg.com/news/articles/2020-03-30/hydrogen-fueled-climate-goals-need-radical-carbon-price-hike.
[3] https://www.icis.com/explore/resources/news/2020/08/03/10537257/eu-hydrogen-strategy-could-cause-power-and-carbon-prices-to-drop and https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.
[4] https://carbonpricingdashboard.worldbank.org/.
[5] https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=54.

fossil fuels used as feedstock for industry in Argentina. However, the current values of carbon pricing applied in these initiatives are all in the range of USD 5-10/t $CO_2$-eq, still below the range needed to trigger investment in low-carbon hydrogen.

Some existing, mature carbon pricing schemes outside Latin America are implementing policy measures to further incentivise low-carbon hydrogen deployment. For instance, in the EU ETS most sectors currently producing hydrogen from unabated fossil fuels are already covered, but since they are considered at risk of carbon leakage, they receive 100% free allocation. The European Union is considering ways to further incentivise the production of low-carbon hydrogen, and could propose specific provisions in the forthcoming revision of the EU ETS. Another carbon pricing policy instrument the European Union is considering is a tendering system for carbon contracts for difference. This would remunerate investors in low-carbon hydrogen by paying the difference between a $CO_2$ strike price and the actual $CO_2$ price in the EU ETS, effectively bridging the cost gap compared to hydrogen production from unabated fossil fuels.[6]

## Investment and financing schemes

Given the early technological maturity of critical hydrogen technologies and the high risks involved, governments have an important role in creating the conditions for private investment, fostering specific business models, helping build the enabling infrastructure and supporting pilot projects. Policy makers' goals must be to foster learning among market players, develop local supply chains and build capacity. The objective is to nurture an ecosystem of actors, generate momentum and build the trust needed to embark on a strategic and credible pathway for the development of hydrogen as an energy carrier.

Roadmaps and the processes that lead to their development will contribute towards this goal. As a part of their roadmaps, many countries are providing an overview of regulatory steps they intend to take in different phases of the deployment strategy. This reassures project developers and investors on the ability to achieve milestones over time, reducing the perceived risk and making projects more bankable (e.g. the guidelines for obtaining permits for hydrogen projects and the elaboration of a specific hydrogen regulation in Chile).

Governments can also directly support projects, for example with the creation of development funds that provide concessional financing and guarantees, or

[6] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

through national development banks, which have already played a crucial role in the deployment of clean energy technologies and local supply chains in the region. Multilateral development banks are already supporting feasibility studies and road-mapping processes across the region (e.g. the Inter-American Development Bank in Chile, Costa Rica, Colombia, Paraguay and Uruguay). They can contribute to the financing of small (but scalable) pilot projects, in particular those related to low-carbon hydrogen from electrolysis, as well as providing technical assistance and capacity building. If enough demand for low-carbon hydrogen develops and technological progress allows it, the large-scale deployment of production technologies is likely to be financed largely by debt, as is the case for wind and solar PV generation. However, low-carbon hydrogen production from fossil fuels may have to rely mostly on equity, as key multilateral institutions are reluctant to fund new fossil fuel-based energy projects.

New capital-intensive enabling infrastructure is needed to integrate hydrogen supply and demand in various sectors. These assets – such as networks of hydrogen refuelling stations, port infrastructure for international trade and large-scale hydrogen transport and storage – are exposed to significant risks, because they depend on the development of both hydrogen consumption and production, as well as being a relatively immature technology. However, infrastructure is crucial for the scale-up of both domestic and international markets. Depending on country circumstances, this may include the expansion of electricity grids to support greater deployment of renewable energy generation capacity. Therefore, government support (e.g. concessional debt financing, grants, tax benefits, co-financing and public-private partnerships) and regional initiatives to connect markets across borders can contribute significantly to the deployment of enabling infrastructure for hydrogen supply chains.

Governments can also play a crucial role in the co-ordination of value chains, removing barriers and anticipating bottlenecks in the development of low-carbon hydrogen as an energy carrier, for example by establishing low-carbon certification and guarantees of origin schemes. Government action can also reduce transmission constraints that prevent low-carbon electricity from reaching potential locations for low-carbon hydrogen production. In Paraguay, one of the world's largest exporters of renewable electricity, solving transmission constraints could in the future allow the country to produce low-carbon hydrogen close to demand centres around the country.

With regard to commercial credit, it is important to note that in the short to medium term, there will be no liquid cross-border market for hydrogen. Therefore, hydrogen production projects are likely to need to secure bankable offtake agreements to be funded. Existing users of fossil-based hydrogen and public transport operators can constitute reliable offtakers in the initial stages if the incentive structures are set accordingly. Another challenge is that at an early stage, production facilities may be closely tied to individual customers and since the value chain involves other potentially high-risk projects (e.g. in renewables producing the electricity or transforming the hydrogen), the credit risk of projects is raised. Within industrial clusters, a solution can consist of establishing intermediaries who sign multi-year contracts for future hydrogen supply and thus reduce perceived risk. In some Latin American countries, currency risk could also affect the bankability of these projects.

## 1. R&D and skills development

Policy makers should promote technological development and innovation as an early focus for hydrogen to play a bigger role in Latin America's energy systems in the long term. Clear guidelines and priorities are needed to orient R&D and innovation activities. In the short term, R&D and pilot projects are essential to unlock larger long-term opportunities, due to their ability to create "convergence spaces" where different actors join forces to develop solutions adapted to the region's needs and circumstances. They also drive down costs and enable the adoption of new technologies. Governments (and hydrogen consortia) can play a critical role in the initial phases, by connecting companies and institutions interested in developing hydrogen uses and production in their activities, as is currently being done in a "matchmaking" initiative in Uruguay. In a region where public resources for R&D are limited, regional scientific collaboration could help countries address common challenges.

Government and industry should see pilot projects testing new technologies as the first step in a process that potentially leads to scaling up their deployment. To ensure that these initial efforts effectively create a basis for broader deployment, pilot projects should be aligned with long-term strategic objectives (either national or company-level).[7] Given existing demand for hydrogen in the oil refining, chemical and iron and steel sectors, R&D and pilots for applications in these sectors can be driven by these industries' own resources and competition, with the support of regulation to encourage private-sector investment in innovation. An example of private sector-led R&D on existing hydrogen uses is the recently announced pilot project to test a 50 kW water electrolyser at the Cartagena refinery, to be carried out by Ecopetrol and the Colombian Petroleum Institute, as

[7] In Brazil, a pilot project which deployed four urban fuel cell buses in São Paulo was discontinued in 2016 after a few years in operation.

well as the broader collaboration between Ecopetrol and Colombia's Ministry of Science, Technology and Innovation. In new applications and complex demonstration projects, public support for basic and applied R&D projects will be important to encourage the development of local value chains for hydrogen.

In Brazil, the National Energy Policy Council identified hydrogen as one of the priorities for energy R&D spending. In Argentina, the scientific and technological development of hydrogen is expected to be one of the pillars of the country's 2030 national hydrogen strategy. From 2021, 260 researchers from 11 countries in Latin America, Spain and Portugal will collaborate in the H2TRANSEL Ibero-American research network, with more than a third of the participating research groups based in Argentina. The project focuses on technologies for low-carbon hydrogen production, transport and storage, and hydrogen use in the transport and power sectors. The programme also seeks to harness synergies between research groups in the region and promote knowledge transfer to the region's private sector. Uruguay's National R&D agency (ANII) has established a sectoral fund to support R&D projects aiming to solve key energy challenges in the country, including the production and export of low-carbon hydrogen and derived products.

Opportunities for R&D and pilot projects, as well as regional collaboration, could also exist in the vicinity of large hydropower plants, including the large cross-border plants of Itaipu (Brazil-Paraguay), Yacyretá (Argentina-Brazil) and Salto Grande (Argentina-Uruguay), where seasonal excess power generation could be harnessed. The Hydrogen Research Centre in Itaipu's technological park is researching alkaline electrolyser technologies to develop local value chains in electrolyser manufacturing, while Brazil's Itumbiara hydropower plant is researching electrolytic hydrogen production and storage technologies.

The private sector has a strong role to play in driving innovation, participating in the creation of local value chains and identifying opportunities for hydrogen deployment in alignment with each company's ESG goals. In this sense, the creation of consortia is proving to be a useful vehicle for co-operation among different actors and for kick-starting developments, such as the H2AR consortium (Argentina), H2Chile, the Costa Rican Hydrogen Alliance and the Colombian, Mexican and Peruvian hydrogen associations.

Moreover, an early focus on training and capacity building could help avoid bottlenecks in the availability of the highly skilled labour that is necessary for large-scale hydrogen application. The Chilean National R&D agency (ANID) is promoting "advanced human capital formation" to address possible skill gaps in the future, a topic that is also emphasised in the H2TRANSEL R&D network.

## 2. Standards and certification

Standards, guarantees of origin and certification schemes are a strategic missing link between incentive structures and the emergence of actual markets, or at least the wider use of hydrogen. Safety standards are a prerequisite for any new use of hydrogen and essential to ensure consumer awareness and acceptability of these new technologies. Low-carbon certification schemes and guarantees of origin for hydrogen production are important to ensure that increased hydrogen consumption leads to lower emissions, to make it an attractive product for consumers looking to reduce emissions and to gain access to emerging international markets for low-carbon hydrogen and derived products.

In parallel with the maturing of different hydrogen production and consumption technologies, standards are being discussed at the national, regional and global levels. Standards will be important enabling factors for regional and international collaboration along value chains, as well as the development of cross-border infrastructure. Government and corporate efforts to harmonise standards at the regional level and participation in the development of new global standards could contribute to the greater deployment of hydrogen technologies in the region.

Several countries in the region have started adapting international standards for safety (ISO 15916), fuel quality (ISO 14687), or electrolysers (ISO 22734) and adopting them into their own standards framework, paving the way for future deployment. Over the course of the coming years, international bodies and forums such as the ISO and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) will be discussing and agreeing regulations and standards that will shape global markets. It will be important for Latin American countries to be involved in such discussions. For example, countries could participate the UN World Forum for the harmonisation of vehicle regulations (WP.29). This could enhance their capacity to benefit from standards developed in leading global markets and thus allow them to harmonise their own with the latest international advancements.

Certification and guarantees of origin schemes will have a role to play in enabling low-carbon hydrogen to gain attractiveness vis-à-vis high-carbon hydrogen, and to ensure that a growing use of hydrogen contributes to emissions reduction goals and energy sector decarbonisation. In the short term, certification schemes can foster low-carbon hydrogen supply and demand at a domestic level, allowing local consumers and producers to prove their emissions reductions, making the product more attractive to end users with emissions reduction targets. In addition to this, the creation of robust and transparent guarantees of origin schemes will help track hydrogen through its supply chain, prove hydrogen is produced from low-carbon sources, and create a potential source of income for low-carbon hydrogen producers. Finally, for countries that are projecting themselves as future low-carbon hydrogen exporters, it is important to follow and, where possible, actively participate in the process of developing certification in future export markets. This can ensure market access for the region's production by having compatible and well-established low-carbon certification schemes.

Countries could build on existing certification or guarantees of origin schemes that are used today for renewable electricity. For example, the Renova platform, hosted by the Chilean independent system operator (Coordinador Eléctrico Nacional), certifies both the origin and destination of renewable electricity. Such schemes could facilitate certification of electrolytic hydrogen produced with low-carbon grid electricity.

A first step towards developing internationally compatible certification mechanisms is to reach a broad international consensus on the methodology to calculate the carbon footprint of hydrogen production pathways. This topic is currently under discussion in the IPHE's Hydrogen Production Analysis (H2PA) Task Force. Currently, the privately owned CertifHy project, which defines criteria for "green hydrogen" and "low-carbon hydrogen", is the only existing certification scheme, but its implementation is being held back due to a lack of agreement regarding its scope and methodology. Australia is developing another international certification and guarantees of origin scheme to track production technology, carbon emissions[8] and production location. Such a scheme could be expanded later to include water consumption and other factors. This approach would allow countries (or regions) to set their own definitions of "low-emission" hydrogen with reference to agreed international standards.

## 3. Regional and international collaboration

Governments in Latin America should collaborate internationally to ensure hydrogen does not develop in silos, isolated from global developments, as this could prevent them from benefiting from major technological improvements and unlocking opportunities for international trade.

Energy systems in Latin America are currently interconnected rather than integrated, and existing interconnection infrastructure for both power and natural gas trade tend to have low utilisation rates, especially in South America. Identifying regional complementarities can help accelerate hydrogen development and

[8] Scope 1 refers to all direct GHG emissions, while Scope 2 includes indirect GHG emissions from consumption of purchased electricity, heat or steam.

establish regional value chains through economies of scale, increasing the attractiveness to investors. Regional (and international) dialogue and collaboration will be essential to identify the many potential synergies and business opportunities along the hydrogen value chain and to agree on joint action to develop them. Hydrogen deployment in certain applications is reliant on regional collaboration, including decarbonising long-distance transport, which will require the co-ordinated and compatible development of refuelling and charging infrastructure to support cross-border mobility.

Regional collaboration can help fund larger joint R&D projects, pooling and optimising the use of limited resources and focusing on co-developing technologies that are relevant for the region, such as applications in high-altitude mining or decarbonising the power supply in the Caribbean islands.

Neighbouring countries could also leverage existing cross-border infrastructure to accelerate learning on both sides of the border and to develop enabling infrastructure. The large hydropower plants between Argentina, Brazil, Paraguay and Uruguay could support pilots requiring small volumes of electrolytic hydrogen for new applications. Some of the existing gas pipelines connecting Chile and Argentina are currently underutilised and go through some of the best areas for hydrogen production. They could in the future be good candidates for repurposing to handle pure hydrogen as part of a network enabling regional exports through ports on the Pacific and Atlantic. Regional collaboration can also leverage mechanisms currently in place, such as the Central American Integration System (SICA), which fosters regional deployment of clean energy technologies and could start working on the topic. Existing initiatives and institutions could adopt a similar approach, such as the Regional Energy Integration Commission (CIER) for Latin America and the Caribbean. At the international level, valuable forums on hydrogen include initiatives driven by government (CEM H2 Initiative, IPHE, IEA Hydrogen Technology Collaboration Programme), business (Hydrogen Council), and academia (H2TRANSEL).

The potential for the region to export low-carbon hydrogen and derived products creates a need to establish dialogue with potential importers,[9] work with them to identify and tackle possible barriers (such as regulation and tariffs and non-tariff barriers) and closely follow developments and emerging regulatory frameworks in those markets. In the European Union, the "Fit for 55" package under the bloc's Green Deal is expected to address topics that could be important for Latin America's prospects as a potential exporter to the market, including guarantees of

[9] In July 2021, the governments of Chile and the Netherlands issued a joint statement on low-carbon hydrogen trade.

origin and emissions thresholds for low-carbon fuels and industrial products. International collaboration would enable the region to benefit from lessons learned from international experience and best practice on policies and regulations, as well as technical support and technology transfer.

### Table 4 Participation of Latin American countries in selected international hydrogen initiatives

| Initiative | Countries |
|---|---|
| International Organization for Standardization (ISO) Technical Committee 197 (Hydrogen technologies) | AR (member), BR (observer) |
| International Partnership for Hydrogen and Fuel Cells in the Economy | BR, CL, CR |
| Clean Energy Ministerial Hydrogen Initiative | BR, CL, CR |
| IEA Hydrogen Technology Collaboration Programme | No government participation Hychico (sponsor) |
| Mission Innovation – Clean Hydrogen Mission | CL (co-lead) |

Notes: AR = Argentina; BR = Brazil; CL = Chile; CR = Costa Rica.

# Recommendations for policy makers

The next decade will be crucial for the long-term prospects of hydrogen in Latin America's clean energy transitions. Governments can take action now to ensure that their countries are ready to harness hydrogen's long-term decarbonisation potential, and that it creates opportunities for economic and social development for their citizens.

Considering the early stages of maturity of several end-use technologies, new applications for hydrogen may not have a sizeable impact on emissions by 2030, but their long-term decarbonisation and economic development potential is considerable, particularly in industry and transport. In the following sections we present the report's conclusions in the form of recommendations for policy makers seeking to develop hydrogen in Latin America.

## Define a long-term vision for hydrogen in the energy system

National strategies and roadmaps are vital to orient the development of hydrogen towards the sectors and applications that are most relevant to each country. These strategic documents should:

- Consider all steps of the hydrogen value chain, from production to end uses, including existing hydrogen demand in the country.
- Identify strategic sectors and opportunities in the short, medium and long term, together with their regulatory and infrastructure needs.
- Establish credible but ambitious targets and milestones, covering both low-carbon hydrogen production and existing and future demand in key sectors, and include mechanisms to track progress and revise them as technologies reach maturity.
- Ensure alignment with a wider decarbonisation strategy, and complementarity with policies and programmes to promote other clean energy technologies that could be the main drivers for decarbonisation in certain sectors, such as direct electrification in transport.
- Develop a vision for the country's position in the future hydrogen industry, considering technological and industrial capabilities and opportunities to leverage existing infrastructure and value chains, and support the creation of national and regional ecosystems to facilitate early deployment.

- Consider developments in other parts of the region and seek complementarities and synergies.
- Establish co-ordination mechanisms with the private sector, including financial services, to ensure their investments and initiatives complement public sector-led efforts, are aligned with strategic objectives and create opportunities for citizens.

# Identify near-term opportunities and support initial deployment of key technologies

While hydrogen technologies are not expected to have a major impact on Latin America's energy systems in the short term, the actions that policy makers take between now and 2030 will be crucial to harnessing their long-term potential for emission reductions and economic opportunities.

Decarbonising current demand is a major opportunity to ramp up low-carbon production and reduce emissions in the near term. For new uses, small-scale pilot projects are crucial to unlock new technologies that could drive demand in the longer term. In countries with little existing demand for hydrogen, initial efforts should focus on technologies that could have a significant impact on emissions in the longer term, such as heavy transport, shipping and aviation. Governments can also support the initial creation of hydrogen ecosystems by establishing public registries and matchmaking initiatives aimed at connecting companies and institutions interested in incorporating hydrogen technologies into their activities, including across national borders.

**Table 5 Principal opportunities for low-carbon hydrogen deployment in Latin America to 2030**

| Sector | Current use of hydrogen | Low-carbon hydrogen supply | | Policy/ regulatory actions | Timeframe for large-scale deployment |
|---|---|---|---|---|---|
| | | Opportunities | Challenges | | |
| Oil refining | Used primarily to remove impurities (e.g. sulphur) from crude oil and upgrade heavier crudes | Retrofit (or build new) natural gas-based production with CCUS<br><br>Replace merchant hydrogen purchases, or part of the onsite production, with hydrogen from low-carbon electricity | Availability of $CO_2$ transport and storage sites (NG w/CCUS)<br><br>Close integration of hydrogen production and use with other refinery processes<br><br>Hydrogen production cost influence on refining margins | Low-carbon fuel standards<br><br>Renewable fuel obligations<br><br>Fiscal incentives<br><br>Fuel taxation<br><br>Carbon pricing<br><br>Public support for CAPEX/OPEX | Late 2020s |

| Sector | Current use of hydrogen | Low-carbon hydrogen supply: Opportunities | Low-carbon hydrogen supply: Challenges | Policy/ regulatory actions | Timeframe for large-scale deployment |
|---|---|---|---|---|---|
| Chemical production | Feedstock for ammonia and methanol production, and used in several other smaller-scale chemical processes | For ammonia production: Retrofit (or build new) hydrogen production with CCUS<br>Mix electrolytic hydrogen into existing natural gas-based production | Availability of $CO_2$ transport and storage sites<br><br>Hydrogen storage is needed to use electrolytic hydrogen beyond process flexibility limits<br><br>Urea and methanol production will still require a source of carbon | Low-carbon fertiliser labels/certification<br><br>Fiscal incentives<br><br>Carbon pricing<br><br>Public support for CAPEX/OPEX | Late 2020s |
| Iron and steel | DRI-EAF process route accounts for 14% of the region's crude steel production and requires hydrogen in a mix of gases | Retrofit DRI facilities with CCUS, or inject electrolytic hydrogen into existing natural gas-based production<br><br>Blend electrolytic hydrogen by injection into blast furnaces | Impact on margins in a sector facing strong competition from producers outside the region | Low-carbon steel labels/certification<br><br>Low-carbon public procurement schemes<br><br>Grants/R&D funding<br><br>Fiscal incentives<br><br>Carbon pricing<br><br>Public support for CAPEX/OPEX | Late 2020s (for hydrogen blending in blast furnaces and DRI)<br><br>Post-2030 for 100% hydrogen DRI |
| Transport | Limited to 2 fuel cell buses (in Brazil and Costa Rica) and 4 fuel cell cars in Costa Rica | Hydrogen could help decarbonise transport modes where direct electrification is not an option<br><br>Cars and buses can contribute to near-term demand for hydrogen, while trucks and shipping are possible larger-scale demand in the long-term | Further technological improvements needed<br><br>Infrastructure requirements<br><br>High impact of fuel costs on margins<br><br>Regional compatibility for cross-border applications | ZEV mandates<br><br>ZEV public procurement schemes<br><br>Differentiated vehicle registration taxes<br><br>Low-carbon fuel standards<br><br>Direct purchase subsidies or support schemes to build refuelling infrastructure<br><br>Differentiated port charges and transit fees (shipping) | Late 2020s for LDVs and buses<br><br>Post-2030 for long-distance applications (trucks and shipping) |

Note: ZEV = zero-emissions vehicle.

# Support early financing schemes and reduce investment risk

Mobilising capital for hydrogen will require specific sources of finance and risk management mechanisms at different stages of technological development, with more public support expected during the early stages. As low-carbon hydrogen technologies move from demonstration and pilot projects to large-scale deployment in the medium and longer term, and the sector becomes more mature and competitive, risk perceptions could improve and more commercial-rate private capital would be expected.

Once hydrogen surpasses the pilot stage, it is critical that governments have the right investment frameworks in place to encourage the deployment of hydrogen technologies best suited to each country's clean energy transition. In this regard, a determined national hydrogen strategy with clear targets and milestones, as well as tracking processes, can already contribute to setting a stable trajectory for investors and project developers to follow, increasing the reliability of market formation and encouraging actors to explore opportunities.

In an initial phase, public-private partnerships and concessional loans from national and multilateral development banks, as well as blended finance instruments, could help fund the first projects and set the sector on track. Business models need to be adapted to the initially scattered production and demand points, and governments can help in this phase by fostering joint action by consortia and acting as a matchmaker between potential suppliers and consumers of low-carbon hydrogen, including international stakeholders.

In addition, along a similar trajectory to renewable energy, public resources could be necessary to support the broader deployment of clean hydrogen technologies before they reach cost-competitiveness, albeit with important differences, such as the fact there are currently no hydrogen equivalents to the power purchase agreements. Across the board, different measures could play a role in this, ranging from policies that stimulate demand, conducive taxation frameworks (including tax incentives and carbon pricing) and sectoral targets, to economic instruments that mitigate initial high cost barriers and mechanisms that monetise co-products (such as flexibility for power systems or oxygen co-produced from water electrolysis). Early co-ordination with the financial sector – to ensure they understand how hydrogen projects work, how different risks can be mitigated, and so on – is critical to ensure that the supply of finance does not become a bottleneck for the smooth implementation of project pipelines.

Later, when markets reach greater maturity and hydrogen technologies are deployed at larger scale, concessional instruments and support measures could be gradually phased out as the role of both development banks and governments shifts towards catalysing projects rather than providing direct financial support. In this regard, a predictable long-term approach will allow for strong initial support while avoiding artificial boom and bust cycles which could prove detrimental to deployment.

# Focus on R&D and skills to reap benefits beyond emission reductions

Technological development is essential to unlock the opportunities that hydrogen could bring to the region's energy systems. An early focus on innovation could help develop technological solutions adapted to local priorities and conditions, in alignment with wider energy and climate goals. Considering the limited amount of resources available for research, regional collaboration between researchers could accelerate work on applications relevant to the region, improve the use of public resources and, in the future, promote the development of regional value chains. International partners will be needed to gain experience while building regional capabilities to create knowledge and manufacture equipment where the region can be competitive. For instance, potential electrolysis targets in the region could push electrolyser manufacturers to open factories in Latin America or local manufacturers to scale up their own capabilities.

Private-sector initiatives, such as national hydrogen consortia and associations, can play an important role in aligning the efforts of individual companies and identifying future commercial opportunities. These industry initiatives should also include academia in order to identify common positions on R&D priorities, optimise investment and maximise knowledge transfer. An early focus on skills development could help create opportunities and prevent future bottlenecks in human resources as the industry develops.

Developing capabilities across the hydrogen value chain, such as equipment manufacturing, hydrogen production, infrastructure development and end uses, could bring additional benefits beyond emission reductions, including economic development, jobs and opportunities for investors. To maximise these benefits and ensure that they create opportunities for all, engagement and co-ordination between the public and private sectors, as well as academia and civil society, should be a policymaking priority from the initial steps of the planning process. This co-ordination is also essential to ensure effective communication and increase the level of understanding of these emerging technologies among potential consumers, service providers and funders, and in society more generally, as well as managing expectations around the speed of uptake.

# Use certification schemes to incentivise the production of low-carbon hydrogen and create market opportunities

Hydrogen can only play a role in Latin America's clean energy transitions if it is low-carbon. Certification and guarantees of origin schemes are essential to ensure this, and should be as technology-neutral as possible to encourage future innovation. Establishing appropriate certification mechanisms should be an early priority for the region, as their design and implementation are often long processes.

Certification schemes can also make low-carbon hydrogen more attractive to potential consumers, such as companies seeking to reduce their emissions in line with their ESG commitments or corporate energy and climate targets. In addition to this, robust and transparent systems of guarantees of origin allow producers to prove that their hydrogen is from low-carbon sources. In the longer term, having well-established low-carbon certification schemes and guarantees of origin for hydrogen production will also enable countries to access emerging import markets for premium low-carbon products derived from hydrogen, such as low-carbon steel and fertilisers, and eventually low-carbon hydrogen or hydrogen carriers.

To capture these opportunities, the region's low-carbon hydrogen certification mechanisms and guarantees of origin should be compatible with those being developed in future import markets. As a region with the ambition to become a low-carbon hydrogen powerhouse, Latin America should actively participate in international fora and initiatives from their outset, giving the region the opportunity to participate in shaping the future hydrogen markets.

# Co-operate regionally and internationally to position Latin America in the global hydrogen landscape

Over the next decade, Latin American countries will face many similar challenges in developing the production and use of low-carbon hydrogen. Regional dialogue on hydrogen can help find complementarities in future hydrogen production, transport and use and identify future regional trade opportunities.

Co-ordination of innovation activity and R&D networks could help optimise the use of public resources to develop solutions to regional energy challenges, and create technology-based regional value chains. Regional collaboration is essential to foster sustainable mobility, which will require compatible infrastructure and standards for zero-emissions vehicles (including battery and fuel cells) and low-carbon shipping and aviation across the region. Decarbonising freight transport, through a combination of sustainable mobility technologies, could be a promising focus area for regional collaboration in Latin America, for example by identifying strategic corridors for different infrastructure as part of a holistic framework.

Countries can find opportunities to accelerate progress across the region by capitalising on existing cross-border infrastructure, such as gas pipelines and large binational hydropower plants, and existing energy integration schemes. They can also build on regional alliances to promote clean energy technologies, such as the 70% renewable capacity target for 2030 set by the RELAC initiative.[1]

At the global level, Latin America can benefit significantly from actively participating in global initiatives and forums from their early phases, and seeking opportunities for international collaboration on hydrogen, such as via IPHE, CEM-H2I, MI-H2 and others. In particular, establishing permanent regional structures for co-operation would allow a co-ordinated approach for the region while maintaining national autonomy. Hydrogen should not develop in national or regional silos. This could prevent countries from benefiting from technological improvements discovered elsewhere, taking advantage of economies of scale at regional level or harnessing opportunities for international trade.

[1] https://ledsgp.org/2019/12/latin-america-and-the-caribbeans-historic-commitment-towards-renewable-energy/?loclang=en_gb.

# Annex

## Pipeline of low-carbon hydrogen projects in Latin America

| Name | Country | Partners | Year | Technology | Announced size | End use | Status |
|---|---|---|---|---|---|---|---|
| Hychico, Comodoro Rivadavia | AR | Hychico Hydrogenics | 2008 | Alkaline electrolysis | 120+60m$^3$ $H_2$/hr | Power sector | Operational |
| $H_2$ARMMONIA | AR | H2AR | | SMR/ATR+CCUS Electrolysis | 176 kt $H_2$/yr | Ammonia | Early stages |
| Pico Truncado Experimental Plant | AR | Municipality of Pico Truncado Federal government of Santa Cruz | 2005 | Alkaline electrolysis | 100m$^3$ $H_2$/day | Transport (hybrid CNG/$H_2$) | Idle |
| UFRJ hydrogen-powered boats | BR | COPPE-UFRJ | | Hybrid ethanol-hydrogen powertrains | Up to 100 passengers | Maritime passenger transport | Early stages |
| UFRJ fuel cell bus | BR | COPPE-UFRJ | 2012 | Electrolysis | | Road transport (fuel cell bus) | Operational |
| Base One | BR | Enegix Black & Veatch | 2025 | Electrolysis | 600 kt $H_2$/yr | Exports | Early stages |
| Porto do Açu Fortescue Ammonia Project | BR | Fortescue Porto do Açu | | Electrolysis | 250 kt $NH_3$/yr | Ammonia | Early stages |
| Porto de Suape | BR | Qair Brasil Government of Pernambuco | | Electrolysis | | | Early stages |
| Renewstable Barbados | BB | HDF | | PEM electrolysis and fuel cell | 15 MW electrolysis 3 MW fuel cell | Power sector | Early stages |
| AES Gener ammonia project | CL | Aes Gener | | Electrolysis | 850 MW renewable capacity | Ammonia | Early stages |
| Cerro Pabellón Microgrid 450 kWh Hydrogen ESS | CL | Enel EPS | 2017 | Electrolysis | 50 kW electrolysis | Power sector | Operational |
| H Valle Sur | CL | TCI Gecomp | | Electrolysis | | Forestry (trucks) | Early stages |
| Haru Oni, Phase 1 | CL | ENEL AME HIF ENAP Siemens Porsche | 2022 | Electrolysis | 750 000 litres of methanol/yr | Synthetic fuels | Early stages |
| Haru Oni, Phase 2 | CL | ENEL AME HIF ENAP Siemens Porsche | 2024 | Electrolysis | 55 million litres synfuel/yr | Synthetic fuels | Early stages |
| Haru Oni, Phase 3 | CL | ENEL AME HIF ENAP Siemens Porsche | 2026 | Electrolysis | 550 million litres synfuel/yr | Synthetic fuels | Early stages |

| Name | Country | Partners | Year | Technology | Announced size | End use | Status |
|---|---|---|---|---|---|---|---|
| HNH | CL | AustriaEnergy Ökowind EE | 2026 | Electrolysis | 1400 MW electrolysis | Ammonia | Early stages |
| Hoasis | CL | TCI Gecomp | | Electrolysis | 102 kt $H_2$/yr | Ammonia and methanol | Early stages |
| HyEx Phase 1 | CL | ENAEX ENGIE | 2023 | Electrolysis | 26 MW electrolysis | Ammonia | Early stages |
| HyEx Phase 2 | CL | | | Electrolysis | 780 MW electrolysis | Ammonia | Early stages |
| Hy-Fi | CL | CORFO | 2025 | Electrolysis | 650t $H_2$/day | | Early stages |
| METH2 Atacama | CL | Sowitec | | Electrolysis | 300 MW electrolysis | Methanol | Early stages |
| Walmart forklifts | CL | Walmart ENGIE | | Electrolysis | 159 hydrogen-fuelled forklifts | Forklifts | Early stages |
| Ecopetrol 50k W electrolyser | CO | Ecopetrol | 2022 | Electrolysis | 50 kW electrolysis | Oil refining | Under construction |
| Costa Rica Transportation Ecosystem Project | CR | AdAstra | 2017 | PEM electrolysis | 1 $m^3$/hr | Road transport | Operational |
| Costa Rica Transportation Ecosystem Project | CR | AdAstra | 2021 | PEM electrolysis | 3 $m^3$/hr | Road transport | Under construction |
| ClearGen | FR | HDF | 2019 | PEM fuel cell | 1 MW fuel cell | Power sector | Operational |
| CEOG | FR | HDF | 2022 | PEM electrolysis and fuel cell | 16 MW electrolysis 3 MW fuel cell | Power sector | Early stages |
| Energía Los Cabos | MX | HDF | | PEM electrolysis and fuel cell | 35 MW electrolysis 9 MW fuel cell | Power sector | Early stages |
| Tarafert low-carbon ammonia | MX | Tarafert | | | | Ammonia/urea | Early stages |
| Delicias Solar | MX | Delicias Solar | | Electrolysis | 35 MW electrolysis | Grid blending | Early stages |
| ECB Omega Green biofuel project | PY | ECB Group Paraguayan Government | 2024 | | 53 kt $H_2$/yr | Advanced biofuels | Early stages |
| Petropar pilot | PY | Petropar | | Electrolysis | 3 production plants in the country | Road transport and shipping | Early stages |
| NewGen | TT | Tringen 2 Yara Government of Trinidad and Tobago | 2024 | Electrolysis | 170-185 MW electrolysis | Ammonia | Early stages |
| H2U | UY | MIEM ANCAP UTE | | Electrolysis | 1.5-5 MW electrolysis | Road transport | Early stages |

Notes: AR = Argentina; BB = Barbados; BR = Brazil; BO = Bolivia; CL = Chile; CO = Colombia; CR = Costa Rica; FR = France; MX = Mexico; PY = Paraguay; TT = Trinidad and Tobago; UY = Uruguay.

# Abbreviations

| | |
|---|---|
| ATR | auto-thermal reforming |
| BEV | battery electric vehicle |
| BF-BOF | blast furnace-basic oxygen furnace |
| CAPEX | capital expenditure |
| CCS | carbon capture and storage |
| CCU | carbon capture and utilisation |
| CCUS | carbon capture, utilisation and storage |
| CNG | compressed natural gas |
| CNPE | National Council for Energy Policy (Brazil) |
| $CO_2$ | carbon dioxide |
| $CO_2$-eq | carbon dioxide equivalent |
| CORFO | Chilean Development Agency |
| DRI | direct reduced iron |
| DRI-EAF | direct reduced iron-electric arc furnace |
| EOR | enhanced oil recovery |
| EPE | Energy Research Office (Brazil) |
| ESG | environmental, social and governance |
| ETS | emissions trading system |
| FCEV | fuel cell electric vehicle |
| GHG | greenhouse gas |
| HVO | hydrotreated vegetable oils |
| IPHE | International Partnership for Hydrogen and Fuel Cells in the Economy |
| ISO | International Organization for Standardization |
| MeOH | methanol |
| LCV | light commercial vehicle |
| LCOH | levelised cost of hydrogen |
| LDV | light-duty vehicle |
| LNG | liquefied natural gas |
| LPV | light passenger vehicle |
| LHV | lower heating value |
| NG | natural gas |
| $NH_3$ | ammonia |
| OPEX | operating expenditure |
| PEM | polymer electrolyte membrane |
| PV | photovoltaic |
| RELAC | Renewables in Latin America & the Caribbean |
| R&D | research and development |
| SICA | Central American Integration System |
| SMR | steam methane reforming |
| w/ | with |
| w/o | without |
| ZEV | zero-emissions vehicle |

# Units of measure

| | |
|---|---|
| bcm | billion cubic metres |
| GW | gigawatt |
| hr | hour |
| kg | kilogramme |
| km | kilometre |
| $km^2$ | square kilometre |
| kt | thousand tonnes |
| kW | kilowatt |
| $kW_e$ | kilowatt electrical |
| kWh | kilowatt hour |
| MBtu | million British thermal units |
| Mt | million tonnes |
| MW | megawatt |
| MWh | megawatt hour |
| t | tonne |
| yr | year |

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Hydrogen
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