NEW CLIMATE INSTITUTE

Case study

THE LANDSCAPE OF GREEN HYDROGEN IN COLOMBIA

Colombia is a promising producer and exporter of hydrogen, given its rich renewable energy resources, strategic geographical location, and stable economy and policy framework. Green hydrogen could feed to domestic industry to substitute imports (such as fertiliser and steel), partially replace fossil fuel export revenues, and potentially reuse some fossil-related distribution and export infrastructure. To contribute to a just and sustainable transition, the development of green hydrogen should ensure that the benefits trickle down to the population, for example, through jobs in the renewable energy industry, and thus alleviate poverty, unemployment, and inequality in the country. Green hydrogen could also contribute to the integration of a high share of renewable energy in the grid, as it can serve to store energy and complement the drought-vulnerable hydro power.

This case on green hydrogen in Colombia is part of NewClimate's broader work on the role of green hydrogen in a just, Paris-compatible transition. As part of our work, we also developed cases on India and Namibia and a background report which delves into the sustainable development and climate considerations of green hydrogen production in developing and emerging economies. A third output will be published in 2024 focused on analysing the role of multilateral development banks in supporting green hydrogen initiatives.

KEY DEVELOPMENT INDICATORS

Colombia is an upper middle-income country of 52 million people at the northern tip of South America, with economic activity centralised in rapidly growing urban areas. GDP growth is driven mostly by the service sector (value added ~55-60% of GDP) and industry (value added ~25% of GDP) [1]. Oil and coal are the most important export commodities, followed by services and agricultural products, where most products have a relatively low complexity [2]. Despite the large exports of fossil energy, Colombia is experiencing a trade deficit, importing refined petroleum, broadcasting equipment, cars, medical products, and fertilisers [3].

Key development challenges include a high share of population living in poverty, which the strong economic growth in the recent decade has not mitigated. Inequality in Colombia is amongst the highest globally, socioeconomic mobility is low, and labour markets need to become "more efficient and inclusive" [1], [4].

The current government, in power since August 2022, has promised a shift in social justice and environmental policy. The National Development Plan 2022-2026 includes five main transformations: territorial planning around water; human security and social justice; right to food; productive transformation, internationalisation, and climate action; and subnational convergence [5].

ENERGY SECTOR OVERVIEW

Colombia has already reached nearly 100% electricity access, including recently in rural areas [1]. About 70% of Colombia's electricity is produced through renewables, mostly hydropower vulnerable to long-lasting dry seasons, the remaining 30% are covered by gas, coal and oil plants [6]. Variable renewable energy sources like solar and wind today play a negligible role in the electricity mix [7] **(see → Figure 1)**.

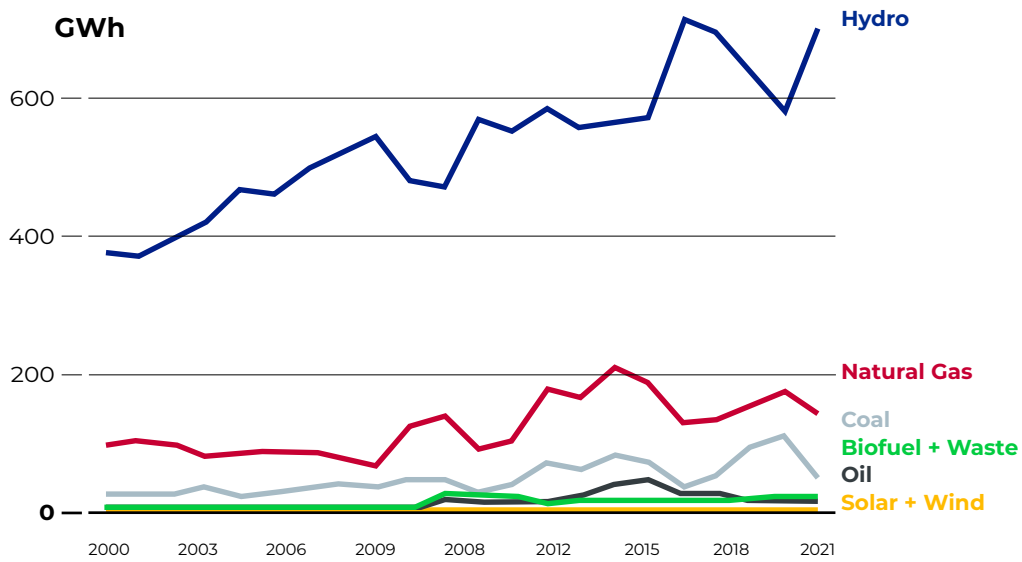

Figure 1:
Sources of Colombia's electricity generation

Source: Authors based on IEA data.

Colombia is working towards further decarbonisation of the electricity sector as part of its net-zero greenhouse gas target for 2050. The country does not have an official renewable energy target. The most ambitious scenario in the National Energy Plan 2020-2050 released by the Colombian Mining and Energy Planning Unit (UPME) expects the installed capacity of non-conventional renewable energy sources (excluding hydropower) to reach nearly 6 GW by 2030 and nearly 20 GW by 2050. This corresponds to a share of about 15% of total primary energy supply in 2050 [8].

CURRENT STATUS OF HYDROGEN AND DERIVATIVES

Colombia currently produces 0.15 megatons (Mt) of hydrogen annually for consumption in the industry sector. Most of this is "grey hydrogen", that is, hydrogen produced through the process of steam methane reformation, but a small amount is also produced with predominantly hydro-based grid electricity. Hydrogen is consumed primarily in the oil refining industry and the remaining demand is split between fertiliser production, ammonia and methanol synthesis, steelmaking, and minor industrial uses such as float glass production and food processing [9]. Current hydrogen trade is negligible, but Colombia imports significant volumes of hydrogen derivatives such as ammonia, methanol, and fertilisers [10].

In Colombia's Hydrogen Roadmap published in 2021, the Government projects hydrogen demand to increase exponentially by 2050, owing to new applications of "low-carbon hydrogen" mainly in transport and industrial end-uses. The Government defines "low-carbon hydrogen" as both blue hydrogen (hydrogen produced with coal gasification or methane reformation with carbon capture and storage) and green hydrogen (hydrogen produced by water electrolysis using renewable energy) [9].

By 2030, the Government projects that demand for low-carbon hydrogen will reach 0.12 Mt, already meeting 80% of the current demand for grey hydrogen mainly in refining and fertiliser sectors. Developments in this direction are already underway; for example, in 2022, Colombia's state-owned oil company Ecopetrol began producing green hydrogen from solar energy at its refining plant in a pilot project [11]. Such pilot projects in industries that are already hydrogen consumers can test and optimise the technology and bring down production costs over the next decade.

The Government expects hydrogen demand to grow almost seven-fold in ten years to reach nearly 0.8 Mt by 2040, and another 2.5 times to reach almost 1.9 Mt by 2050. This trajectory calls for accelerated renewables deployment, translating to about 10 GW and 24 GW of installed solar and wind power capacity[1] by 2030 and 2050 respectively. Although Colombia has nearly 10 GW auctioned solar and wind capacity in the pipeline, project development has met with environmental licensing hurdles and indigenous resistance [12], [13].

The exponential hydrogen demand growth trajectory is expected to be driven by the transport sector, starting with direct use in heavy- and light-duty road transport and mining trucks until 2040 and the eventual use of low-carbon hydrogen derivatives in maritime (ammonia) and air (synthetic fuels) transport until 2050 [9]. The transport sector is expected to account for 64% of the low-carbon hydrogen demand in 2050. While betting big on low-carbon hydrogen for the decarbonisation of long-haul transport is promising, its application in light-duty road vehicles would not be technically or economically efficient compared to electrification.

The Hydrogen Roadmap also expects that new industrial applications of low-carbon hydrogen will rise steadily between 2030-2050, notably in the mining and steel sectors, but refining is still expected to constitute most of the industrial demand in 2050 [9]. However, such an emphasis on the role of oil refining in 2050 is not compatible with a 1.5°C-aligned development pathway, wherein much of the demand for oil is expected to be replaced with electricity and green fuels. Similarly, Colombia's main mining sectors currently are coal and petroleum, and the planned application of low-carbon hydrogen in mining could potentially be counterintuitive to the just energy transition. Instead, low-carbon hydrogen use for ammonia and fertiliser production should be scaled up to replace heavy import dependence and foster food security.

1 Assuming average wind and solar capacity factor to be 40%, electrolyser efficiency to be 75%, and energy value of hydrogen to be 33.3 kWh.

The Government also plans to use hydrogen as an energy storage option to provide flexibility to the grid and enable the integration of variable renewables, but only to a minor extent (6% in 2030, declining to 2% by 2050) compared to transport and industrial applications [9]. This could be due to the predominance of hydropower, which is a dispatchable renewable energy source well-suited to provide flexibility to a renewables-based power system. However, as the country is vulnerable to long and unpredictable droughts, further exacerbated due to climate change, it could be worthwhile to consider a greater role of low-carbon hydrogen for energy storage, especially since the Roadmap already expects much of the green hydrogen production in Colombia to be grid-based [9].

POLICY FRAMEWORK

The Government of Colombia has set several 2030 targets for low-carbon hydrogen production and consumption in the Hydrogen Roadmap. It aims to produce 0.05 Mt of blue hydrogen annually and to install 1-3 GW of electrolyser capacity for green hydrogen, bringing down the cost of green hydrogen production to USD 1.7/kg, at least in the La Guajira region where wind and solar resources are abundant. It also targets 40% consumption of low-carbon hydrogen in industry and direct use in 2500-3500 fuel cell vehicles by 2030. These targets are expected to require investments worth USD 2.5-5.5 billion and would lead to the creation of 7000-15000 jobs and the abatement of 2.5-3 $MtCO_2$ emissions by 2030.

We roughly translate Colombia's electrolyser capacity target into 3-6 GW of renewable energy capacity requirements and 0.2-0.4 Mt of annual green hydrogen production by 2030[2]. However, the Government's own projections are more conservative, at about 0.07 Mt annual green hydrogen production by 2030 [9].

The levelised cost of producing green hydrogen in Colombia is projected to be one of the lowest in the world and in the region by 2050 [14]. The country expects to leverage this competitive advantage to build a "low carbon export economy" all along the hydrogen value chain and become a logistics and export hub supplying to demand centres in USA, Europe, and Asia. This hub would be located in the La Guajira peninsula, where the Government plans to repurpose existing oil and gas trade infrastructure at strategic ports to cater to low-carbon hydrogen export markets. However, given that the country is currently a net importer of fossil gas, the current scale of hydrogen and ammonia export infrastructure (e.g., liquefaction facilities) at the ports is likely inadequate and would need rapid and expensive upscaling to match export ambitions [15]. The Government expects exports to bring in more than USD 5 billion in revenue in the long term, which is comparable to revenue from current coal exports [9].

It will be important to ensure export orientation is accompanied by local value creation and sustainable development benefits. The Government emphasises job training, reskilling, capacity building, industrial development, and national research and innovation as planned outcomes in its Hydrogen Roadmap.

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Assuming wind capacity factor to be 37%, electrolyser efficiency to be 75%, and energy value of hydrogen to be 33.3 kWh. Until 2030, the Government plans to mostly harness wind resources in La Guajira for green hydrogen production.

The landscape of green hydrogen in Colombia

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However, it does not specify how the development of low-carbon hydrogen will improve access to electricity and drinking water for the local community in La Guajira, where the industry is expected to be concentrated. Active engagement of local communities in the planning and implementation of low-carbon hydrogen projects should be considered as a collaborative and mutually beneficial approach to a just transition [16].

While the Government of Colombia foresees a major role of green hydrogen in the Roadmap to 2050, the proportions of different types of hydrogen in use are expected to depend on their respective cost evolutions. Green hydrogen based on wind energy produced in the La Guajira region is projected to become cost competitive with grey hydrogen by 2029 and with blue hydrogen as early as 2027. Yet, the government expects blue hydrogen to remain in the mix at least until 2040 [9]. Blue hydrogen is viewed as a "transition fuel" that can easily be phased in with existing gas distribution infrastructure for existing applications (i.e., refining and fertiliser production) and contribute to the development of the overall hydrogen transport, distribution, and storage value chain in the country.

However, there are several pitfalls associated with blue hydrogen. First, most existing blue hydrogen projects use the captured carbon for enhanced oil recovery, which would make the emissions reductions impact of blue hydrogen questionable [17]. Second, prolonged use of blue hydrogen based on fossil fuels can leave the country exposed to stranded asset risks and would be inconsistent with its political commitment to work towards phasing out oil and gas production as a "Friend of the Beyond Oil and Gas Alliance" [18]. It would thus be prudent to minimise reliance on blue hydrogen and phase in green hydrogen production at the earliest, particularly given that it is projected to become cost competitive in four years.

The Colombian government plans to support low-carbon hydrogen development in four main ways – establishing legal and regulatory enablers, creating market development instruments, providing support for infrastructure deployment, and encouraging technical and industrial development. Under legal and regulatory enablers, planned measures include developing a low-carbon hydrogen taxonomy, guarantees of origin, and simplifying permitting procedures to create a fair, transparent, and stable regulatory framework that encourages private investments. One of the recommended actions in the Roadmap is to review and eliminate "unnecessary" environmental permitting procedures to which low-carbon hydrogen projects will be subjected [9]. It will be crucial to ensure, however, that adequate social and environmental safeguards remain in place to ensure low-carbon hydrogen development is not based on the exploitation of local communities and natural resources, notably in the La Guajira region.

Under the second axis, market development instruments like tradeable emissions certificates, innovative public-private financing mechanisms, and other

mechanisms promoting consumption and production of low-carbon hydrogen are also being considered to help make it competitive. Developers can already avail fiscal incentives such as exemption from customs duties, value added taxes, accelerated depreciation, and income tax deduction of 50% of the investment under the Energy Transition Law of 2021, which classifies both blue and green hydrogen as Non-Conventional Energy and Non-Conventional Renewable Energy sources respectively. Public funds earmarked for non-conventional energy can also support the financing and implementation of viable projects across the low-carbon hydrogen value chain [9]. Most recently in March 2022, the Government launched +H_2 Colombia programme with an initial endowment of USD 1 million to finance feasibility studies for low-carbon hydrogen projects [19].

Further, infrastructure support measures would include feasibility assessments and plans for natural resource utilisation (including water, renewables, geological storage, carbon capture and storage), blending in natural gas networks, fuelling stations, and ports and shipyards to facilitate coordinated infrastructure deployment. Finally, technological and industrial development measures would promote research and innovation, build institutional and personnel capacity, and enable local value creation in a sustainable manner [9].

RECENT ENGAGEMENT WITH MULTILATERAL DEVELOPMENT BANKS

Colombia works together with various multilateral development banks (MDBs) to support the development of a sustainable energy future, including the reliability of access to electricity and increasing the share of non-conventional renewables. Various activities have an explicit focus on green hydrogen:

The Inter-American Development Bank (IDB) support for Colombia's Hydrogen Roadmap: Through Technical Cooperation projects, IDB has supported the development of Colombia's Hydrogen Roadmap, as well as its implementation through the introduction of policy measures [20]. IDB sees Colombia as one of the hydrogen hubs of Latin America, with good chances of exporting green hydrogen to Europe [16].

World Bank, via the Hydrogen for Development Partnership (H4D), supports the development of green hydrogen in various countries including Colombia through knowledge exchange, technical assistance, and financing. For Colombia, the partnership has provided capacity building to develop green hydrogen projects and to comply with international standards in terms of guarantees of origin [21]. In 2022, World Bank approved a loan of USD 1 billion to support the policy framework for the energy transition, including the development of green hydrogen and encouraging private sector participation.

The project document stresses the role of green hydrogen to diversify export structures, but also the domestic use of green hydrogen for fertiliser production to decrease the emissions intensity of the agricultural sector [22].

Via the **Climate Investment Fund's Renewable Energy Integration programme**, Colombia has received USD 70 million. The programme works towards integrating a high share of renewables in the grid and includes funding for feasibility studies for green hydrogen production.

Interestingly, both the World Bank and the Climate Investment Fund (CIF) activities pick up on the need for integrating green hydrogen production in the grid through changes to the policy framework and infrastructure. This is a deviation from current pilot projects in Colombia and different to the IDB's recommendations which suggest that off-grid electrolysers or renewable energy installations can produce green hydrogen at lower costs because they are exempt from taxes and grid levies [16].

Colombia also works bilaterally with Germany and Spain on green hydrogen: It is member of the PtX-hub initiated by the German government through which it participates in trainings and knowledge exchanges. It has signed memoranda of understanding with both **Germany and Spain** to work together on the energy transition, including the development of green hydrogen [23], [24]. In addition, the Colombian government and the **European Investment Bank (EIB)** have signed a joint Declaration of Intent to support the just energy transition in Colombia, with particular emphasis on green hydrogen [25].

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