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Comparison of Hydrogen Related Policies and Achievements between Latin America and Europe

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Hydrogen, and green hydrogen will be one of the dominant energy sources of the future, the application of which will support the achievement of existing decarbonisation targets and contribute to the smooth integration of renewables into energy infrastructure based on its energy storage characteristics. The goal of this study is to compare hydrogen-related policies and achievements between Latin America and Europe. The research employs a comprehensive literature review to assess existing policy frameworks, technological advancements, and economic impacts in both regions. Preliminary findings indicate that while Europe has developed a more structured and well-funded hydrogen economy, Latin America shows great potential due to its renewable energy resources but lags in policy coordination and investment. The significance of this work lies in identifying key gaps and opportunities, aiming to provide policy recommendations that can enhance hydrogen development strategies in both regions, ultimately contributing to global decarbonization efforts.

1. Introduction

Hydrogen energy is crucial for the global energy transition, offering clean, sustainable, and versatile potential. It is classified by production methods: green (renewable sources), blue (natural gas with carbon capture), and grey (fossil fuels without carbon capture). While currently dominated by industrial and chemical uses, hydrogen's energy applications are increasingly important.

Fossil fuels currently dominate as the primary source of energy for the world's needs. In 2022, 82 % of the world's primary energy consumption came from fossil sources with an annual increase of 1 % compared to the previous year (Energy Institute, 2023). According to Enerdata (2024) analysis, if current energy and climate protection policies remain unchanged, global primary energy demand is expected to increase further by 2050, rising from nearly 10 Gtoe in 2023 to 13.7 Gtoe in 2050. The development of energy demand is also influenced by the expected growth of the population, which will reach 10 billion people by 2050 according to some scenarios (Wallerstein, 2020).

The energy sector is responsible for 34 % of the world's current greenhouse gas emissions (IPCC, 2022). It is particularly important that the energy sector can be decarbonised as soon as possible. One solution is to replace fossil fuels with renewable sources. In 2022, renewable energy production accounted for 12.3 % of total energy production (IEA, 2023a). The International Renewable Energy Agency (IRENA) forecasts that the share of renewables in total primary energy production will rise to 27 % by 2050 under current policies, and up to 66 % if further commitments are made (IRENA, 2018). Beside solar and wind energy green hydrogen can also play an important role in the future sustainable energy transition and is increasingly recognized as a critical solution for reducing carbon emissions in several sectors.

Europe is leading the world in hydrogen energy development with several ambitious policies and large-scale projects. In Latin America, countries like Chile, Argentina, and Brazil are also making strides, leveraging abundant renewable resources for green hydrogen production. However, despite emerging efforts, the region still faces significant challenges in infrastructure and investment.

Currently, hydrogen production is dominated by grey hydrogen. In 2021, only about 1 % of global hydrogen production was green (IRENA, 2024). Current climate protection targets foresee a significant increase in the

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share of renewable energy, which will include green hydrogen production. According to the IEA's Net Zero scenario, low-carbon hydrogen production should reach 520 Mt by 2050 (IEA, 2021a), while McKinsey forecasts that green hydrogen demand is expected to be between 125 – 585 Mt in 2050 and only 1 – 50 Mt of grey hydrogen will be used (Gulli et al., 2024). To cover this huge growth on the energy side, nearly 28 TW of installed renewable energy capacity will be needed, which will account for 15-25 % of renewable energy production expected in 2050 (Pathak et al., 2023).

Hydrogen's role is expanding, with increasing policies and targets at national and continental levels. The European Union prioritizes hydrogen as an energy vector with ambitious targets, though progress is lagging. Latin American countries aim to become leading green hydrogen producers by 2030, leveraging their renewable energy production. The EU plans to build significant capacities by 2050, while Latin American nations invest heavily in hydrogen production to support the green transition.

The goal of the research is to compare strategic objectives and production results of H_2 deployment in two major regions with different energy backgrounds, aiming to understand the progress of green H_2 production. The comparison highlights the commitment and success of green H_2 strategies in both regions. Analysis of literature and strategy documents was used to the research, alongside with the statistical evaluation of publicly available capacity and production data. It fills a gap by providing a comparative analysis of two distinct regions that prioritize green hydrogen production. By evaluating strategic goals and steps taken, the research offers valuable insights for future green hydrogen strategies.

2. Hydrogen policies in Latin America and in the European Union

In the following section the key policy elements of the two analysed region will be discussed.

2.1 Policy-uptake in Latin America

Latin American countries (LAC) have begun formulating policies and strategies to integrate hydrogen into their energy systems. Brazil launched its National Hydrogen Program (PNH2) in 2020, aiming to develop a hydrogen economy that leverages the country's renewable resources (Ministério de Minas e Energia, 2021). Chile unveiled its National Strategy for Green Hydrogen in 2022, focusing on utilizing the country's abundant solar and wind resources for hydrogen production (León et al., 2023).

Countries in the LAC region are actively developing strategies, legislative frameworks, public policies, regulations, and funding initiatives for green hydrogen (GH_2). Colombia recently enacted a law offering tax incentives and a broad framework for GH_2 projects. Argentina is updating its 2006 national hydrogen law to reflect current advancements. Additionally, nations like Panama, Brazil, Paraguay, El Salvador, Peru, Costa Rica, and Mexico are formulating specific hydrogen legislation (Gischler et al., 2023).

Significant progress in public policies, regulations, and funding for GH_2 is evident across the region. Chile has established guidelines for hydrogen projects and offers financing through the Corporation for Production Promotion (Gischler et al., 2023). The government also plans to grant long-term land use concessions for hydrogen projects. Uruguay created the Green Hydrogen Sectorial Fund to finance projects and assigned hydrogen responsibilities to the Energy and Water Services Regulatory Unit. In Colombia, funding is provided through the Nonconventional Energy Fund, with regulations for hydrogen blending, transport, industry, and environmental considerations in development. Costa Rica is crafting a policy to utilize surplus capacity from its national electrical system for GH_2 (Gischler et al., 2023).

2.2 Policy-uptake in the European Union

Given the broad scope of the European Union's sustainability policies, this article focuses only on hydrogen-related aspects. The EU aims to become the most sustainable continent by 2050, with strategic objectives outlined in the European Green Deal (EGD). The EGD addresses climate protection, sustainable transport and industry, green agriculture, and energy-related issues (e.g. energy efficiency, use of renewable energies) (European Commission, 2021a).

Green H_2 will also play a key role in greening energy supply. These targets are summarised in the EU strategy on Hydrogen (COM/2020/301), adopted in 2020.

The strategy aims to establish a sustainable, efficient, and competitive economy by integrating hydrogen into the energy transition. Key goals include decarbonizing industrial processes and sectors, promoting green H_2 as a clean alternative to fossil fuels, developing a dynamic hydrogen market with integrated infrastructure, including scaling up production, storage, and distribution capacities, aligning policy frameworks to support market growth and integration across EU member states and boosting investments and job creation in the hydrogen sector by fostering innovation and scaling up projects that can contribute to the economy and energy security. These objectives position the EU to become a global leader in hydrogen technologies (European Commission, 2020a).

Beside the EU strategy on Hydrogen there are several other hydrogen-related policies and initiatives focusing on H_2 as a future sustainable energy source, forming a broader framework to support the development of H_2 as a key energy vector. These include following documents and actions: Fit for 55 Package as part of the EGD aiming the reduction of greenhouse gas emissions by at least 55 % by 2030. It includes measures to increase the use of renewable energy, including H_2, across all sectors (European Commission, 2021b). The Hydrogen and Gas Market Decarbonization Package aims to adapt the existing gas legislation to facilitate H_2 use and integrate it into the internal energy market (European Commission, 2021c).
The activities in the field of green H_2 production and utilization are supported by organizational and funding instruments e.g. the Clean Hydrogen Alliance (CHA). CHA was established to bring together industry, governments, and civil society to facilitate the scaling up of H_2 production and its integration into sectors like energy, transport, and industry. The Important Projects of Common European Interest (IPCEI) on Hydrogen are supporting large-scale H_2 projects that can significantly contribute to economic growth, job creation, and competitiveness.

3. Achievements in Hydrogen Deployment in the analyzed regions

In the initial phase of H_2 production, especially green H_2, obtaining complete data is challenging. As of 2019, Latin America and the Caribbean produced over 4 Mt of H_2, mainly in the industrial and oil refining sectors for ammonia, methanol, steel, and refined oil products, primarily using natural gas. This production was concentrated in larger economies and Trinidad and Tobago, mostly on a conventional (natural gas) basis (IEA, 2021b).
Despite being in the early stages, LAC has made significant strides in H_2 deployment. Notably, the region has developed H_2 infrastructure and pilot projects. For example, Argentina's H2Ar project promotes H_2 production and utilization in sectors like transportation and industry (Ministerio de Ambiente y Desarrollo Sostenible, 2020). Uruguay has initiated pilot projects to explore H_2-powered vehicles in urban areas (Lima, 2022), demonstrating LAC's commitment to innovative H_2 solutions. Chile, a frontrunner in H_2 revolution, aims to become global leader in green H_2 exports by 2040 with its ambitious strategy. This has attracted significant domestic and international investment (Gischler et al., 2023). The Chilean government, in collaboration with private partners, has launched various projects across the H_2 value chain (production, storage, distribution, utilization), leveraging abundant solar and wind resources for H_2 production through electrolysis (Inter-American Development Bank, 2021).
The Green Hydrogen Hub in the Atacama Desert aims to use the region's solar energy to produce green H_2 at scale. Chilean companies and international firms are partnering to advance H_2 research, development, and innovation (Inter-American Development Bank, 2021). This momentum has catalysed interest in other LAC countries like Argentina, Brazil, and Colombia, which are developing their own H_2 strategies to decarbonize various sectors (Gischler et al., 2023). Regional initiatives, such as the Latin American Hydrogen Association (ALAHy) and the Hydrogen Initiative of the Americas (H2@A), are promoting knowledge sharing, capacity building, and joint efforts to accelerate H_2 adoption across Latin America.
The European Union leads in planned green H_2 production capacities. Europe has around 0.8 Mt p.a. of clean H_2 operational capacity as of 2023. This includes 740 kt p.a. of low-carbon H_2 and about 60 kt p.a. from renewable sources, equivalent to 700 MW of electrolysis capacity, in 2022 there were 180 MW electrolysis capacity deployed in Europe (Hydrogen Council, 2023). The European Hydrogen Strategy sets a target of 10 Mt of renewable H_2 production and 40 GW of electrolyser capacity by 2030. Europe is strategically expanding its H_2 production capabilities, with numerous projects and investments. Europe accounts for a significant portion of the 13 Mt p.a. clean H_2 production announced globally through 2030, though only 5 % of these projects are committed (Hydrogen Council, 2023).
The total installed electrolysis capacity in Europe grew from 85 MW in 2019 to 162 MW by mid-2022, with projections reaching up to 500 MW by the end of 2023. Europe aims to achieve 6 GW of installed electrolyser capacity by 2024, supported by government initiatives and rapid project announcements (IEA, 2023b). This increase in capacity is intended to boost green H_2 production using renewable electricity from wind and solar energy. The European Clean Hydrogen Alliance currently has 1241 clean H_2 production projects in its database. Of these, 35,9 % target H_2 production (446), the rest are split between H_2 distribution (163), industrial applications (172), transport (240), buildings (77) and the energy sector (143) (ECHA, 2024). Of the known European green H_2 projects, 15 % are operational, 35 % have completed feasibility studies, and nearly 9 % have reached final investment decision (Green Hydrogen Europe, 2024). The largest planned project in the project list will be capable of producing 143,000 t of H_2 (ECHA, 2024).

4. The Levelized Cost of Green Hydrogen in Latin America

Most national H_2 strategies use Levelized Cost of Hydrogen (LCOH) analyses to assess competitiveness and opportunities. The Latin America and Caribbean (LAC) region stands out in the international H_2 export market due to its varied production costs. LCOH varies significantly across and within LAC countries, influenced by the type and quality of renewable energy sources and geographical locations. Data suggests LCOH will decrease in most countries by 2030 and 2050, potentially falling below 2 US$/kg by 2050, aligning with global H_2 export ambitions (Gischler et al., 2023).

H_2 demand in LAC is expected to grow, driven by both established and new applications. In 2019, the region's H_2 demand was 4.1 Mt, projected to rise to nearly 7 Mt by 2030 (IEA, 2021). Major demand comes from Argentina, Brazil, Chile, Colombia, Mexico, Trinidad and Tobago, and Venezuela, mainly for producing ammonia, methanol, and oil-refined products. Traditional uses will continue, with new applications emerging in cement, steel, and transportation. These applications also include derivatives like green ammonia and green methanol (Gischler et al., 2023).

To achieve target costs for green H_2 and green ammonia production in LAC, countries must boost renewable energy capacity, as electricity costs make up to 75 % of GH_2 production expenses (IEA, 2022). Some LAC countries already rely heavily on renewables: Costa Rica, Paraguay, and Uruguay generate nearly 100 % of their energy from renewables, while Brazil, Ecuador, Peru, Panama, El Salvador, and Colombia generate over 60%, mainly from hydroelectric power (Paredes, J., 2017).

Despite progress, LAC faces challenges in scaling up H_2 technologies, including limited infrastructure, high production costs, and regulatory barriers. Financing and investment gaps also hinder large-scale deployment. However, these challenges offer opportunities for collaboration, innovation, and capacity building. Addressing these obstacles can help Latin America unlock H_2's potential for economic growth and climate change mitigation (Gischler et al., 2023).

Latin America and Europe recognize the importance of collaboration to accelerate H_2 deployment and address common challenges. Initiatives like research partnerships, technology transfer programs, and policy dialogues facilitate knowledge exchange and capacity building. The European Commission's LAC Initiative on Sustainable Development and Climate Change prioritizes H_2 cooperation (European Commission, 2020b). Projects like the EU-LAC Clean Energy Facility support joint efforts to develop H_2 infrastructure and demonstrate innovative applications (ECLAC, 2022). These collaborations enhance the resilience and competitiveness of H_2 value chains in both regions.

In Europe, the levelized cost of H_2 from renewable sources is influenced by technological advancements and project scale-up. Costs vary by country, depending on local electricity costs from renewables and the scale of electrolysis installations. For example, H_2 production costs using low-temperature water electrolysis can be calculated based on electricity sources like wholesale, PV, onshore, and offshore wind, with adjustments for specific country conditions (European Hydrogen Observatory, 2024).

5. Challenges and Opportunities

Comparing H_2 policies in LAC and EU shows differences in maturity and implementation. Brazil and Chile have national H_2 programs focusing on renewable energy for green H_2. Colombia offers tax incentives, and Argentina is updating its 2006 H_2 law (Gischler et al., 2023). Europe's H_2 strategy, driven by the EGD, aims for carbon neutrality by 2050. The EU Hydrogen Strategy (2020) promotes green H_2 production and infrastructure, supporting a cross-border H_2 market and global leadership in H_2 technologies (European Commission, 2020a). While both regions are developing legislative frameworks, Europe's approach is more comprehensive. LAC countries like Chile and Colombia are working on regulations and financing for H_2 projects. In Europe, policies like the Fit for 55 Package and the Hydrogen and Gas Market Decarbonization Package drive H_2 integration across sectors (European Commission, 2021b; 2021c).

Latin America is establishing funds for H_2 projects, like Chile's financing options and Uruguay's Green Hydrogen Sectorial Fund. Europe supports H_2 initiatives with mechanisms like the Clean Hydrogen Alliance and IPCEI, aiming to lead the global H_2 market. Both regions face high production costs and limited infrastructure but have opportunities for innovation and economic growth, especially in areas with abundant renewable resources.

Life cycle emissions from H_2 production vary, with EU achieving lower emissions using renewables, while LAC can minimize its carbon footprint with solar and wind power (Palmer et al., 2021). Europe has more structured funding mechanisms like the Clean Hydrogen Alliance supporting large-scale H_2 projects for economic growth and global competitiveness and IPCEI on Hydrogen supporting large-scale H2 projects aimed at economic growth, job creation (European Commission, 2020a). This coordinated investment reflects Europe's ambition to lead the global H_2 market.

H_2 deployment in Latin America and Europe faces challenges like high production costs, limited infrastructure, and regulatory barriers. Overcoming these requires investment, policy alignment, and innovation. Ensuring social inclusion and environmental sustainability is crucial for an equitable transition to H_2-based economies. These challenges also offer opportunities for innovation, job creation, and economic development, especially in regions with abundant renewable resources (Escamilla-García, 2023).
Quantifying and evolving the environmental impacts of green H_2 production is challenging. Life cycle impacts differ between Europe and Latin America due to regional energy sources and technologies. In Europe, green H2 production via electrolysis powered by renewables like solar PV has significantly lower GHG emissions compared to traditional methods like steam methane reforming (SMR). Solar PV electrolysis can achieve emissions around a quarter of those from SMR, though factors like electrolyser efficiency and operational sensitivities affect this (Palmer et al., 2021). Latin America, with its abundant solar and wind resources, also has potential for low life cycle emissions in H_2 production, offering substantial environmental benefits and carbon footprint minimization.

6. Conclusions

Latin America is at a pivotal moment in its transition towards a sustainable energy, with H_2 playing a central role . By implementing strategic policies, fostering innovation, and promoting collaboration, LAC can accelerate the adoption of H_2 technologies and reap the benefits of a clean energy economy. Continued efforts to overcome challenges and capitalize on opportunities will be essential in realizing the region's H_2 potential and achieving long-term sustainability goals. Currently, the European Union is a leader in terms of electrolyzed capacity installed and is making available significant subsidies to increase green H_2 production and use. Europe benefits from advanced infrastructure, including extensive gas pipelines that can be repurposed for H_2, and advanced technology for both production and utilization of H_2. The continent is also a leader in electrolyser manufacturing, a critical component for green H_2 production. In summary, while Europe is advancing rapidly with substantial infrastructure and policy support for green H_2, Latin America holds significant potential due to its renewable energy resources. The focus in Latin America is more on exporting green H_2, whereas Europe is developing an integrated market that encompasses both production and extensive utilization across various sectors. The evolution of H_2-related policies and achievements in Latin America and Europe underscores the growing importance of H_2 as a key enabler of the global energy transition. By leveraging their respective strengths and fostering collaboration, both regions can unlock the full potential of H_2 to drive sustainable development and mitigate climate change. Continued efforts to address challenges, promote investment, and foster international cooperation will be essential in realizing a future powered by clean H_2. In the long term, successful green H_2 strategies will rely on boosting renewable energy production alongside effective strategic planning. Using green H_2 as an energy carrier aids in decarbonizing critical industries and allows for the long-term storage of surplus renewable energy. This ensures that the necessary increase in renewable energy capacity does not compromise grid stability and could offer a double win situation. This article primarily compares the strategic directions and project activities of the two regions in green H_2. The remainder of the research will delve into the differences between the regions using statistical analyses. It will examine the underlying factors, their interrelations, and interactions, leading to concrete recommendations for improved strategy implementation.

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