

Water constraints as a critical boundary for renewable hydrogen deployment in Mexico: a hydrological perspective

Abstract

Renewable hydrogen has emerged as a strategic vector for decarbonization in Mexico, particularly in the context of industrial transformation, energy security, and international climate commitments. However, the rapid expansion of hydrogen production — especially via water electrolysis — raises fundamental hydrological questions that remain insufficiently addressed in current planning frameworks. This opinion argues that water availability, quality, and governance constitute critical boundary conditions for renewable hydrogen deployment in Mexico. By framing hydrogen production as a hydrological demand embedded within catchment-scale water systems, this contribution highlights key risks, trade-offs, and opportunities associated with surface water, groundwater, seawater desalination, and treated wastewater. Integrating hydrological science with energy policy is essential to avoid unintended impacts on water security, ecosystems, and social equity.

Keywords: renewable hydrogen, water–energy nexus, electrolysis, water governance, hydrological planning, Mexico

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Introduction

Renewable hydrogen has gained global relevance as a cornerstone of deep decarbonization strategies, particularly for hard-to-abate industrial sectors and energy storage applications.^{1,2} In Mexico, recent policy discussions and regulatory initiatives frame hydrogen as an opportunity to enhance industrial competitiveness and integrate the country into emerging international value chains, with a primary focus on energy supply and industrial decarbonization.³

Despite this momentum, most hydrogen roadmaps and feasibility studies prioritize electricity supply, costs, and emissions, while water is often treated as a secondary or implicit input. From a hydrological perspective, this omission creates a critical blind spot in hydrogen planning. Electrolysis-based hydrogen production represents a new, continuous, and spatially concentrated water demand embedded within the broader water–energy–hydrogen nexus, where water scarcity increasingly emerges as a limiting factor for large-scale deployment.⁴

Electrolysis as an emerging hydrological demand

Water electrolysis requires high-purity water, typically produced through pre-treatment chains such as reverse osmosis and deionization.² While the volumetric water requirement per kilogram of hydrogen is often perceived as marginal, recent assessments show that water footprints vary significantly depending on source water, treatment pathways, and scale of deployment, with important implications for basin-level water management.⁵

From a hydrological systems viewpoint, the central issue is therefore not only water source selection, but also long-term supply reliability under climate variability and extreme events, which remain insufficiently addressed in current hydrogen planning exercises. This concern is particularly relevant in Mexico, where many regions with high renewable energy potential coincide with structurally water-stressed basins and overexploited aquifers.⁶

Water sources: hydrological Trade-offs and risks

Different water supply options for hydrogen production involve distinct hydrological implications. Allocating surface water or groundwater to hydrogen production in closed or over-allocated basins may intensify competition with agricultural, urban, and environmental water uses.⁶

Seawater desalination is frequently proposed for coastal hydrogen hubs, as it reduces direct pressure on freshwater systems; however, it introduces energy penalties, brine disposal challenges, and cumulative coastal impacts that require integrated basin-to-coast system analysis.^{2,7} Treated municipal wastewater offers clear advantages from a circular water perspective, yet its availability is geographically constrained and dependent on treatment infrastructure and regulatory conditions, as highlighted in global assessments of wastewater reuse policy and infrastructure.⁸ Across all options, hydrological viability depends not only on average availability, but also on robustness under drought conditions and future climate change scenarios.⁹

Governance and allocation: an overlooked dimension

Mexico's water governance framework is structured around concessions, basin councils, and priority uses defined under historical demand patterns.⁶ Hydrogen production, as an emerging industrial water use, does not yet have a clearly articulated position within this framework. Without explicit hydrological criteria in hydrogen permitting and policy design, projects may effectively function as implicit water reallocators, intensifying social conflicts in already stressed basins. Similar governance challenges have been identified internationally within the broader water–energy–hydrogen nexus literature.^{4,1}

Toward a hydrologically informed hydrogen strategy

A sustainable hydrogen strategy for Mexico requires the systematic integration of hydrological science into energy planning. Key elements include basin-scale water availability assessments linked

to projected hydrogen demand, explicit accounting of consumptive water use across electrolysis and pre-treatment stages, priority use of non-conventional water sources where hydrologically viable, and incorporation of climate change scenarios into water supply reliability analyses. Such integration would position water not as a constraint, but as a design variable for resilient and socially legitimate hydrogen systems.

Conclusion

Renewable hydrogen represents an important opportunity for Mexico's decarbonization agenda, yet its long-term viability depends on water systems that are already under significant stress. Although electrolysis does not rival agriculture or urban supply in volumetric terms, its spatial concentration, quality requirements, and governance implications make water a critical boundary condition. This short communication highlights the need for hydrologically informed hydrogen policies to ensure that climate mitigation efforts do not undermine water security or exacerbate socio-environmental inequities. Advancing hydrogen deployment without a hydrological lens risks shifting, rather than resolving, sustainability challenges across interconnected water–energy systems.

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Conflicts of interest

The author declares there is no conflict of interest.

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