IFC International Finance Corporation
WORLD BANK GROUP

Creating Markets, Creating Opportunities

UNLOCKING OPPORTUNITIES: GREEN HYDROGEN IN EMERGING MARKETS

MAY 2025

1

INTRODUCTION

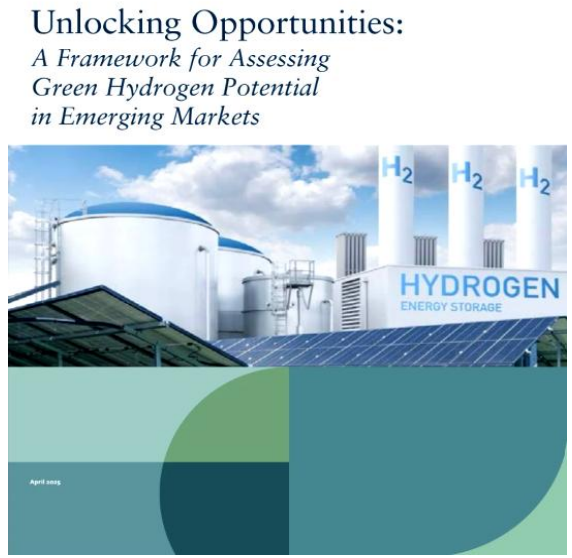
Green hydrogen can be a key tool to decarbonize many hard to abate sectors such as fertilizers, steel, chemicals and long-distance transport.

This report provides a framework for developers, investors, and policymakers to explore the potential of green hydrogen and create opportunities for new industries, foster job creation, and enhance resilience to address global challenges.

https://www.ifc.org/en/insights-reports/2025/unlocking-potential-a-framework-for-assessing-green-hydrogen-potential

UNLOCKING OPPORTUNITIES

This report builds on prior WBG reports incorporating recent observations from our experience



Why focus on Emerging Markets?

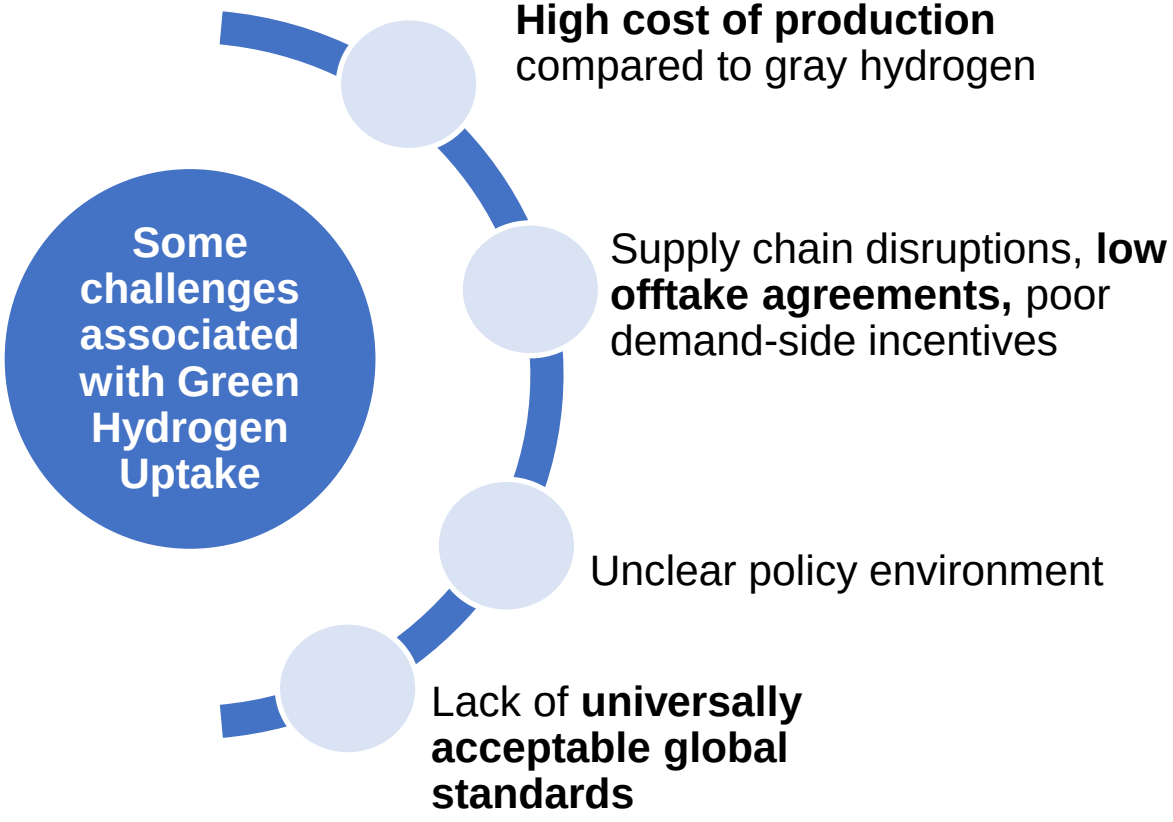
"**Emerging markets can play a significant role in the global production of low-emission hydrogen** while creating new opportunities for their economies".

"Countries with cheap resource abundance can leverage green hydrogen production **to strengthen their domestic economies,** especially those with advanced industrial sectors".

"This strategy can **minimize vulnerability to macroeconomic shocks;** and decarbonize hard-to-abate sectors".

GREEN HYDROGEN UPTAKE CHALLENGES

In general, the development of green hydrogen projects at scale has faced several challenges.



Threats to green hydrogen bankability

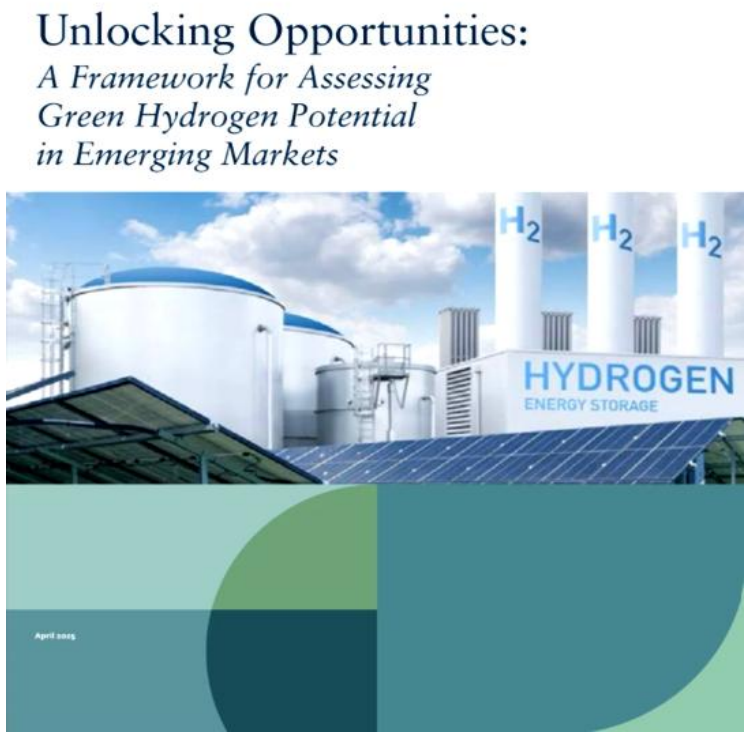
- High cost of production, transportation, storage and financing. Green hydrogen **costs between $4.50 to $12 per kilogram** (compared to $1-$2 for gray hydrogen).
- Negotiations ongoing on offtakes – but **only 1 mm Mt binding** (as of May 2024) vs total grey hydrogen market of 90-100 mmt.
- **Supply chain disruptions stemming** from various factors including geopolitical shifts, technological limitations, logistics, and **inconsistent political support.**
- The **absence of common international standards** could create barriers to international trade in green hydrogen.

UNLOCKING OPPORTUNITIES

Report Objectives and Contents

- **Chapter 2:** **outlines** the primary barriers to scaling up green hydrogen production
- **Chapter 3:** **delineates** crucial factors for establishing a successful green hydrogen market
- **Chapter 4:** **provides** an overview of project level bankability considerations in green hydrogen projects.

- **Chapter 2:** Barriers to Scaling Green Hydrogen in Emerging Markets
- **Chapter 3:** Pillars for Green Hydrogen Market Growth
- **Chapter 4:** Project-Level Considerations for Green Hydrogen



2

BARRIERS TO SCALING GREEN HYDROGEN IN EMERGING MARKETS

BARRIERS TO SCALING GREEN HYDROGEN IN EMERGING MARKETS

- Cost of electricity
- Cost of electrolyzers
- Operations & Maintenance

Main Contributors to Green Hydrogen Production Costs

	Renewable Electricity	Electrolyzer	Operations and Maintenance
Total[a]	Renewable electricity accounts for more than 50% of the total cost of producing green hydrogen.	Electrolyzer capital expenditure and operations account for approximately 30% to 35% of the total cost.	Operations, maintenance, water, storage, transport, and "other" expenditures account for approximately 15% to 20% of the total cost.
CAPEX	**RE infrastructure: 30% of CAPEX** This includes the costs of setting up solar panels or wind turbines to provide the necessary renewable electricity for the electrolysis process. The exact share depends on scale and the local cost of renewable energy infrastructure and resource availability.	**Electrolyzers: 40% of CAPEX** Electrolyzers are a significant portion of the CAPEX due to the advanced technology and materials required. This percentage can vary with the type of electrolyzer (PEM, alkaline, or solid oxide) and country of manufacture.	**Site development and infrastructure: 30% of CAPEX** This category includes hydrogen storage, transport, and all auxiliary systems required for the electrolysis process, such as water supply and purification, power electronics, cooling systems, and other support infrastructure.
OPEX[b]	**Electricity costs: 55% of OPEX** Electricity, including electrolyzer utilization, is the largest component of OPEX for green hydrogen production since the electrolyzers require a significant amount of power to operate. The cost of electricity depends on the source (such as solar or wind) and market conditions.	**Maintenance and repairs: 20% of OPEX** Regular maintenance and repairs are crucial for keeping electrolyzers, renewable energy systems, and other infrastructure in good working order. This includes scheduled servicing, replacement of worn parts, and unscheduled repairs.	**Plant operations: 20-40% of OPEX** This category includes general maintenance, water supply, labor costs, insurance and safety, and other miscellaneous operational costs.

Source: Original table for this publication.

Note: CAPEX = capital expense; OPEX = operating expense; PEM = proton exchange membrane; RE = renewable energy.

a. All costs are approximate and vary depending on project design, location, and infrastructure.

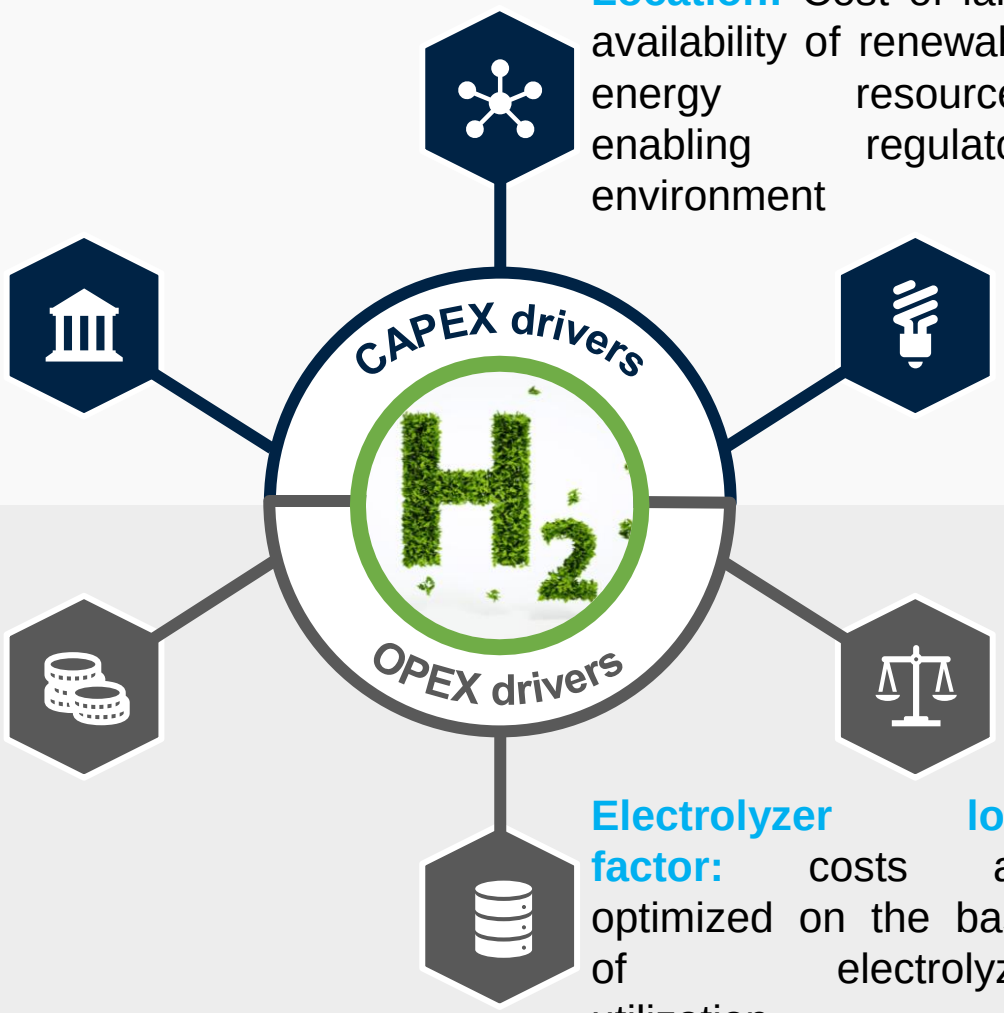
b. Total OPEX costs average between 30% and 40% of CAPEX assumed over a project life cycle of 20 years, which is typical for infrastructure projects. Ratio of OPEX to CAPEX is calculated as OPEX per year times 20 years over CAPEX.

FACTORS INFLUENCING OPEX & CAPEX

The main challenge to scaling up green hydrogen is the economics. Besides the costs of green hydrogen production, the costs of transforming, transporting, and storing remain high.

Location: Cost of land, availability of renewable energy resources, enabling regulatory environment

Electricity Cost & Project Scale: ability to source power from an existing grid and benefit from economies of scale



Technology choice: Type of electrolyzer technology and battery storage technology.

Electricity Costs: depends on location, time of day, type of RE contract

Location: costs for water supply, labor, E&S can vary depending on the location

Electrolyzer load factor: costs are optimized on the basis of electrolyzer utilization.

BARRIERS TO SCALING GREEN HYDROGEN IN EMERGING MARKETS

Financing costs

- Country risk profile
- Developer's track record
- Developer's credit worthiness
- Technology maturity
- Availability of subsidies, incentives, grants to encourage offtake
- Debt-equity mix

Case Study 1 - NEOM Green Hydrogen Project Production Cost

3	equal joint venture partners with more than **80 years** of combined experience across ACWA Power, Air Products and NEOM (*owned by PIF)*
$8.4 billion	Total investment, expected **COD 2027**
$6.1 billion	non-recourse financing, by 23 financial institutions (*Saudi Industrial Development Fund, National Infrastructure Fund, local, regional, international banks covered and uncovered ECA tranches*)
2.2GW	alkaline electrolyzers to produce more than **1.2MMTPA** of green ammonia initially for export, but recent shift in focus to domestic consumption
30-year	exclusive green ammonia off-take agreement with Air Products ("A" rating)
70:30	Debt-equity ratio

3

PILLARS FOR GREEN HYDROGEN MARKET GROWTH

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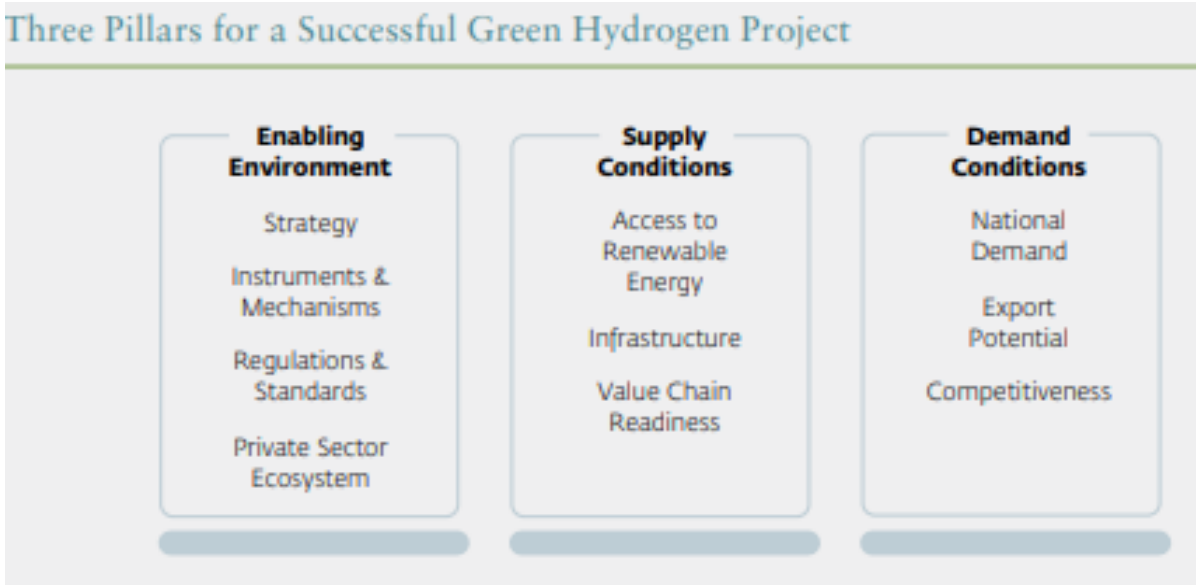
Understanding a country's role in the global hydrogen market starts with assessing its national priorities and potential to create demand through competitive scalable supply.



- Creating a strong enabling environment for green hydrogen deployment requires a robust combination of national policies, supporting mechanisms, and collaborative ecosystems.
- Key supply enablers: low-cost renewable energy, infrastructure to store, transport and transform green hydrogen molecules, and readiness of end-use applications
- Demand drivers: Availability of robust policy frameworks and regulations for hydrogen markets to support the development of strong domestic markets and exports strategies

THREE PILLARS FOR A SUCCESSFUL GREEN HYDROGEN PROJECT

There is no one-size-fits-all-menu to create an enabling environment for green hydrogen

Pillar 1 – Enabling Environment

Elements Needed for an Enabling Environment

Established Enabling Environment	Strategy	Nationally Determined Contribution (NDC), net zero goal
		Long-term energy plan
		Hydrogen road map and/or strategy with targets
	Instruments and mechanisms	H_2 tax incentives
		H_2 subsidy programs (including contracts of difference)
		H_2 demand quotas
		RE incentives and regulatory support
		Carbon pricing
	Regulation and standards	Defining green hydrogen
		Legal framework for renewable energy
		Green hydrogen certification
		Safety and technical standards
		Regulation for production, storage, transportation, and trade
	Private sector ecosystem	Industry association, public-private initiatives and partnerships
		Existing green or low-carbon hydrogen projects (active and/or announced)

52 countries had released national hydrogen strategies, with 29 in preparation, at the time of publication.

$360 billion worth of subsidies available to support green hydrogen demand and supply. ~90% in North America, the EU, and Japan.

≤1.0g CO2e/g of H2 incl. upstream methane to point of production + guarantees of origin + renewable-powered electrolysis (*voluntary industry standard developed by Green Hydrogen Organization*)

42 members of the WBG Hydrogen for Development Partnership (H4D), to help catalyze financing for hydrogen investments from both public and private sources.

THREE PILLARS FOR A SUCCESSFUL GREEN HYDROGEN PROJECT

Supply conditions will determine costs

Pillar 2 - Supply conditions

Robust Supply Conditions	Access to renewable energy	Installed RE
		Potential RE
		Grid availability
	Infrastructure	Water availability
		Access to critical raw materials (CRMs)
		Existing industrial infrastructure
		Existing NG infrastructure
		Bulk chemical export
		Existing deep-water ports
		Storage facilities
	Value chain readiness	Electrolysis/FC/FCEV manufacturers
		Industrial gas companies
		Energy utility/oil and gas company with hydrogen experience
		Chemical companies with hydrogen experience
		EPC companies with hydrogen experience
		Active relevant business association/network(s)
		# hydrogen projects (operational or under development)

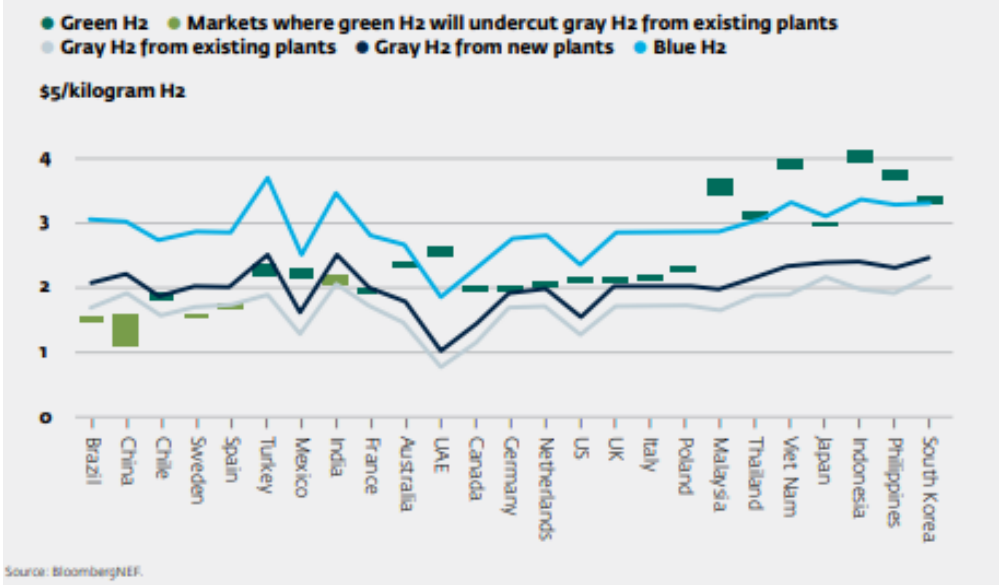
- Cheap, plentiful (to maximize plant's load factor), and consistently available RE is the single most important ingredient in green hydrogen production.
- Water (desalination), Ports, Storage, and Pipelines are required to support the global green hydrogen economy.

THREE PILLARS FOR A SUCCESSFUL GREEN HYDROGEN PROJECT

Countries with good combination of renewables (including hydro) and developed transmission network are best placed

Pillar 2 - Supply conditions: Brazil example

Hydrogen Strategy	Programa Nacional do Hidrogenico (PNH2) published July 2021 by the Ministry of Mines and Energy		
Energy Mix (2022)		INSTALLED	UNTAPPED
	Wind	25.6 GW	288.4 GW
	Solar PV	24.1 GW	282.9 GW
	Hydro	109.8 GW	66.2 GW
Existing Electrolysis Projects	ANNOUNCED	FINANCED	OPERATIONAL
	14	1	1



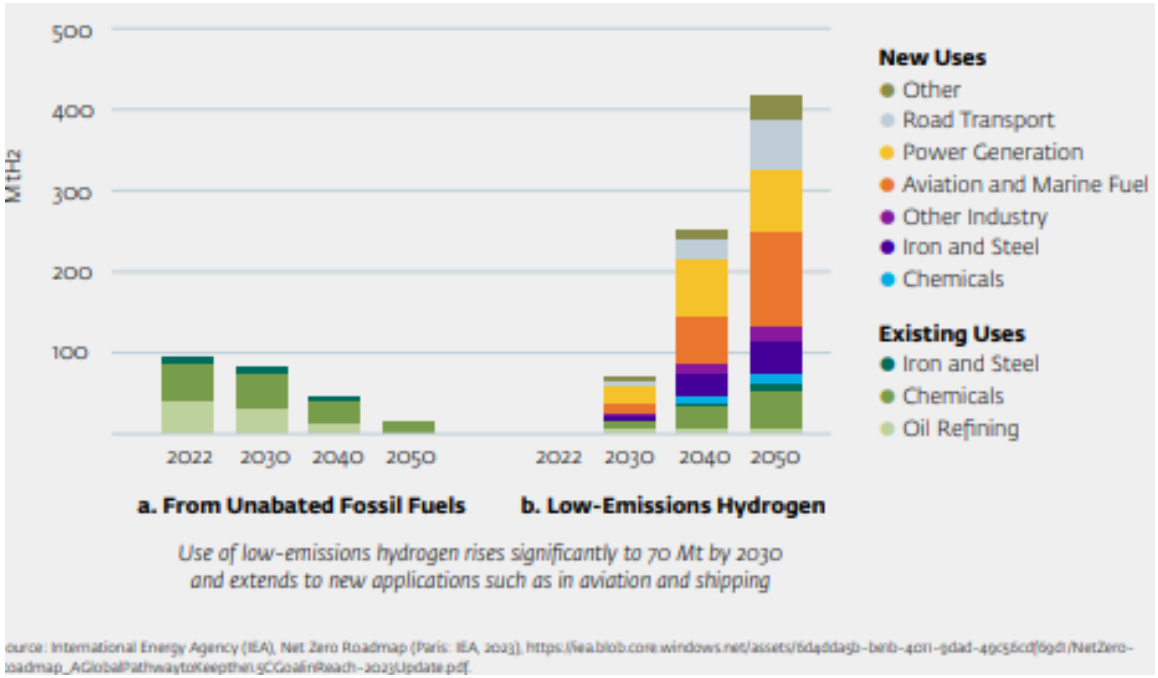
- Latin America's largest electricity market and the sixth largest globally. Boasting the cheapest and most abundant renewable energy in the region
- Renewable energy accounts for 83 percent of its energy mix (well above the global average of 25 percent),
- Its regulatory frameworks and private sector engagement support the development of sustainable solutions, including green fertilizer, clean fuels such as sustainable aviation fuels, energy storage, hydrogen, and wind power projects.

THREE PILLARS FOR A SUCCESSFUL GREEN HYDROGEN PROJECT

Demand conditions will determine the type and level of support required to stimulate demand

Pillar 3: Demand conditions

Attractive demand opportunity	Domestic H2 demand	Current
		Projected
	Export potential	Bilateral conversation/agreements
	Competitiveness	Natural gas costs
		Diesel costs
		Alternative decarbonization technologies



Use of low-emissions hydrogen rises significantly to 70 Mt by 2030 and extends to new applications such as in aviation and shipping

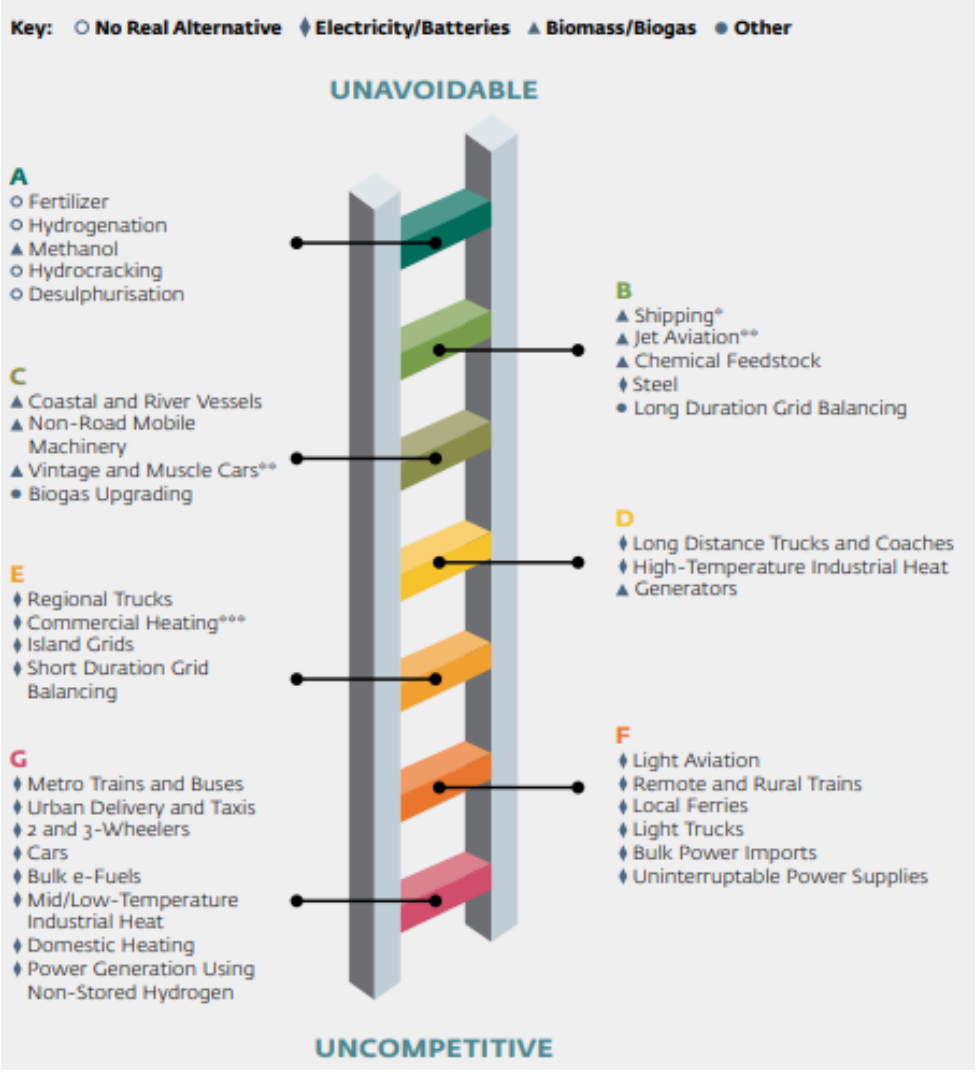
ource: International Energy Agency (IEA), Net Zero Roadmap (Paris: IEA, 2023), https://iea.blob.core.windows.net/assets/6d4d0a5b-be1b-401-9da-49c56cdf69d1/NetZero-oadmap_AGlobalPathwaytoKeepthe1.5CCoalinReach-2023Update.pdf.

- To stimulate demand, a balanced approach of incentives and regulations is necessary and should prioritize the reduction of carbon emissions at the most efficient cost
- 27 EU member states have unanimously adopted the Renewable Energy Directive, to elevate the share of RE in the EU's overall energy consumption to 42.5% by 2030.

THREE PILLARS FOR A SUCCESSFUL GREEN HYDROGEN PROJECT

Policy makers will need to focus on "no regret" demand sectors

Pillar 3: Demand conditions – The (in)Famous Liebrich Ladder



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PROJECT LEVEL CONSIDERATIONS FOR GREEN HDYROGEN

PROJECT-LEVEL CONSIDERATIONS

Hydrogen projects encompass a wide range of considerations at various levels. It is important to understand the risks and opportunities associated with these projects.

Technical Considerations

Economic Considerations

Regulatory Considerations

Environmental Considerations

Dimensions for comprehensive planning and analysis

- Technology selection
- Infrastructure Requirements
- Integration with RE
- Cost-Benefit Analysis
- Financing and Investment
- Market Demand (offtake) and Pricing
- Policy and Regulation
- Permitting and Licensing
- Stakeholder Engagement
- Carbon Footprint

PROJECT FUNDING SOURCES

Multiple funding sources but early-stage development will require concessional funds and grants.

Funding source	Description	Examples
Government grants and subsidies	• **Public funding programs:** Grants, subsidies, or financial incentives to support R & D, demonstration, and deployment of hydrogen technologies.	H2FUTURE Green Hydrogen; U.S. DEPARTMENT of ENERGY; CORFO
Public-private partnerships (PPPs)	• **Collaborative initiatives:** Partnerships to jointly fund and develop hydrogen projects. • **Co-investment models:** Co-investment agreements where public and private partners share project costs, risks, and rewards.	GREEN HYDROGEN CATAPULT; 
Project Finance	• **Debt financing:** Loans secured by project cash flows and assets • **Equity financing:** Equity investment from investors, including institutional investors, private equity firms, venture capitalists, and corporate investors.	IFC; Hy24 ARDIAN

PROJECT FUNDING - OFFTAKE

Most limited recourse financing requires long term offtake with price clauses – remains the biggest obstacle to financing

Key conditions for bankable offtakes

- **Offtaker creditworthiness**: Lenders require creditworthy buyers or entities capable of providing suitable credit support, enhancing confidence in project viability
- **Quality and quantity**: Agreements should specify hydrogen quality standards, quantity requirements, and inspection protocols to ensure compliance and reliability
- **Take-or-pay provisions**: To secure predictable revenue streams, offtake contracts need to include take-or-pay clauses, guaranteeing minimum purchase commitments. Project developers may also require flexible production targets to accommodate reduced plant availability and avoid liquidated damages for underperformance.
- **Price mechanisms**: Flexible pricing structures, such as indexed hydrogen purchase agreements (HPAs), cater to stakeholders' diverse risk profiles and preferences. The most common types of HPAs are either fixed or indexed. In a fixed-price HPA, the buyer agrees to a fixed real price for the entire contract duration, while an indexed HPA is linked to a specific market index, such as inflation
- **Tenor and termination**: Contractual terms should align with project life cycles, incorporating provisions for the maturity of loans and offtake agreements, as well as specifying termination terms and conditions for early termination and force majeure events.

SUMMARY / RECOMMENDATIONS

SUMMARY / RECOMMENDATIONS

Each country will take a unique approach depending on its strengths and weaknesses, and how those align with its priorities across sectors.