DRIVING THE BLUE ECONOMY
TEXAS A&M UNIVERSITY AT GALVESTON

BREAKBULK
EDUCATION DAY

HOUSTON MARITIME Center & Museum

Abstract

Imagine a future where ports operate with zero carbon footprints. That future isn't decades away: it's within our reach today with hydrogen power. Green hydrogen is rapidly emerging as a key solution in the global effort to achieve net-zero emissions, particularly within the maritime industry. As ports and shipping fleets face increasing pressure to reduce their environmental impact, hydrogen fuel presents a compelling zero-emission alternative. Through pioneering advancements across Europe, Asia, Latin America and North America, this research demonstrates how the adoption of hydrogen technologies is transforming global maritime operations. By examining lifecycle analyses from key industry players and adoption milestones in various ports, we reveal how hydrogen is not only accelerating the reduction of carbon footprints but also paving the way for a cleaner, more sustainable future in port operations. With the International Maritime Organization's 2050 targets calling for a 50% reduction in greenhouse gas emissions from international shipping and a complete decarbonization by mid-century, integrating green hydrogen offers a scalable, renewable solution to help ports meet these ambitious climate goals.

Global Hydrogen Projects Across the Value Chain

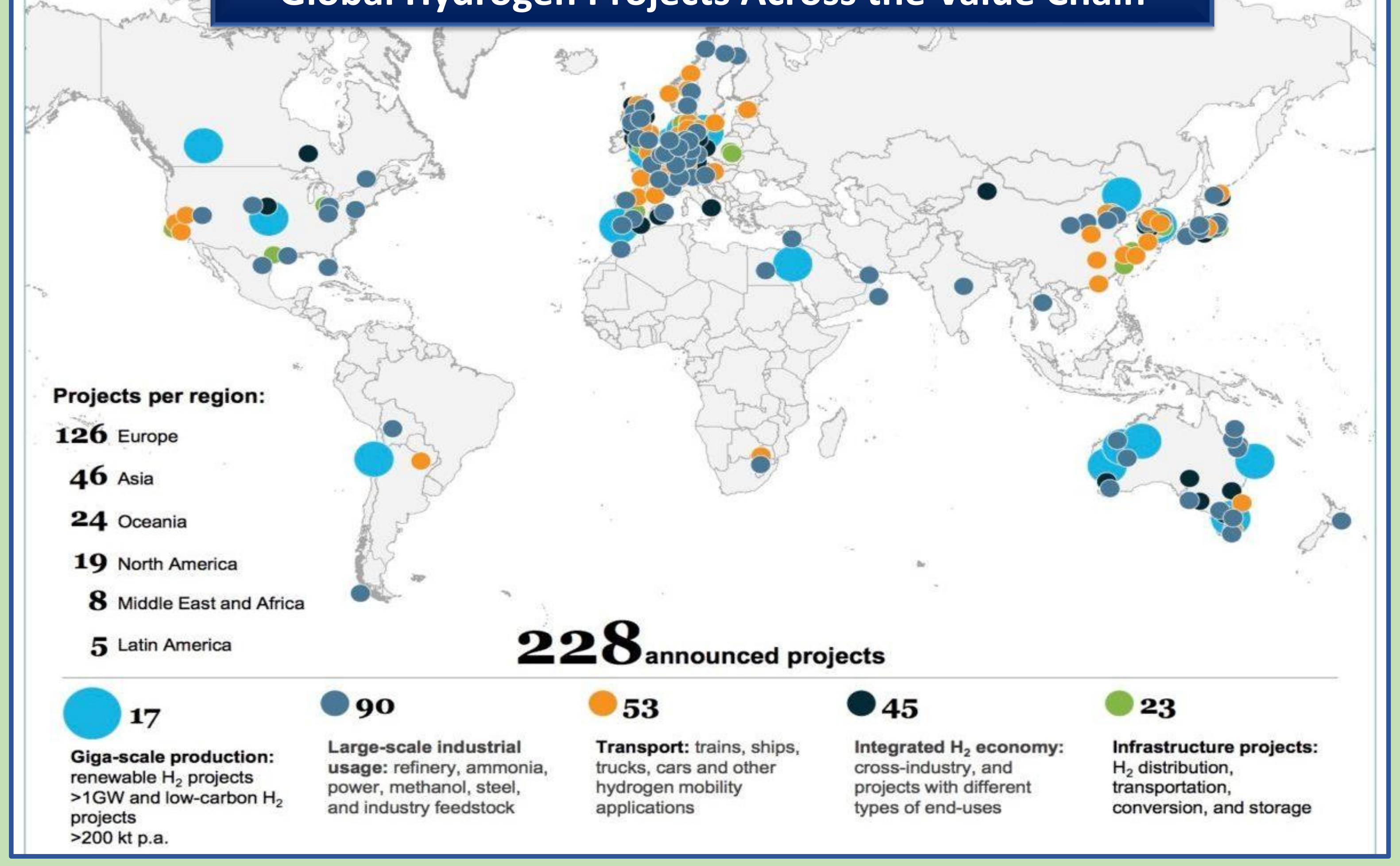

Figure 1: Global hydrogen projects across the value chain

Hydrogen's Role in Port Decarbonization

Hydrogen is increasingly integral to port decarbonization, with key applications including powering port cranes, enabling cold ironing (shore power), and fueling hydrogen-powered vessels, all of which help reduce emissions in port operations. Additionally, hydrogen is being adopted in logistics, with its use in forklifts and trucks further supporting the transition to cleaner, more sustainable port environments. The integration of hydrogen power machines includes; the cargo ship made by Samskip in India, H2-ZE RTG Transtainer Crane made by MITSUI E&S in collaboration with PACECO at the Port of Los Angeles in the United States, and Hyster's ReachStacker (forklift) at the Port of Valencia in Spain.

Figure 2: Samskip

Figure 3: H2-ZE RTG Transtainer Crane

Figure 4: Hyster's ReachStacker

Port Fuel Comparison Chart

Criteria	Green Hydrogen	Liquefied Natural Gas (LNG)	Heavy Fuel Oil (HFO)	Marine Gas Oil (MGO)	Marine Diesel Oil (MDO)
Lifecycle GHG Emissions (gCO_2e/MJ)	0 - 16.4 (gCO_2e/MJ) (zero when produced from renewable energy sources)	94 (gCO_2e/MJ)	90-120 (gCO_2e/MJ)	88.9 (gCO_2e/MJ)	88.9 (gCO_2e/MJ)
Gravimetric Energy Density (MJ/kg)	120 - 142 (MJ/kg)	50 (MJ/kg)	39 - 42(MJ/kg)	42 - 46 (MJ/kg)	43 - 46 (MJ/kg)
Voulmetric Energy Density (MJ/L)	8.5 - 10.1 (MJ/L) High (in fuel cells and fuel cell applications)	25.3 (MJ/L) Moderate to High	37 (MJ/L) Low to Moderate	35.8 (MJ/L) Moderate	37.3 (MJ/L) Moderate
Environmental Impact	Best for decarbonization—no pollutants or greenhouse gases	Reduces emissions; but still produces methane slip	Very high emissions; being phased out	High emissions; decreasing use due to regulations	High emissions; decreasing use due to regulations
Cost	High today (will decrease as technology scales and renewables grow)	Moderate (competitive and growing availability)	Low but increasingly regulated	Moderate to High	Moderate to High
Availability	Limited today (infrastructure being developed)	Widely available (strong infrastructure)	Widely available	Widely available	Widely available
Technological Advancement	High potential (advancements expected, reducing costs and improving efficiency)	Stable (established technology, less room for major change)	Stable (gradually phased out due to emissions concerns)	Stable (regulations tightening)	Stable (regulations tightening)
Future Potential	Very high (as renewables scale, costs decrease, technology matures)	Moderate (still fossil-based, not fully decarbonized)	Very low (being phased out due to environmental regulations)	Low (tightening regulations on sulfur and nitrogen emissions)	Low (tightening regulations on sulfur and nitrogen emissions)

Excellent | Acceptable | Undesirable

Figure 5: Student made green hydrogen comparison chart.

Hydrogen's Lifecycle

Hydrogen's life cycle encompasses production, storage, transportation, and utilization. Green hydrogen, produced by splitting water using renewable energy sources like wind or solar, is the most sustainable option. Unlike blue and grey hydrogen, which rely on natural gas and contribute to greenhouse gas emissions, green hydrogen generates zero carbon emissions during production. After production, hydrogen is stored in high-pressure tanks or cryogenic containers and transported via pipelines, trucks, or specialized liquefied hydrogen tankers. Ports play a vital role in the global hydrogen economy. They produce green hydrogen with renewable energy, store it, and export it to international markets. They can also import hydrogen, storing and distributing it for local use, such as powering fuel cells for electricity or fueling ships. Beyond trade, ports leverage hydrogen to power critical equipment, such as cranes, forklifts, and other port machinery.

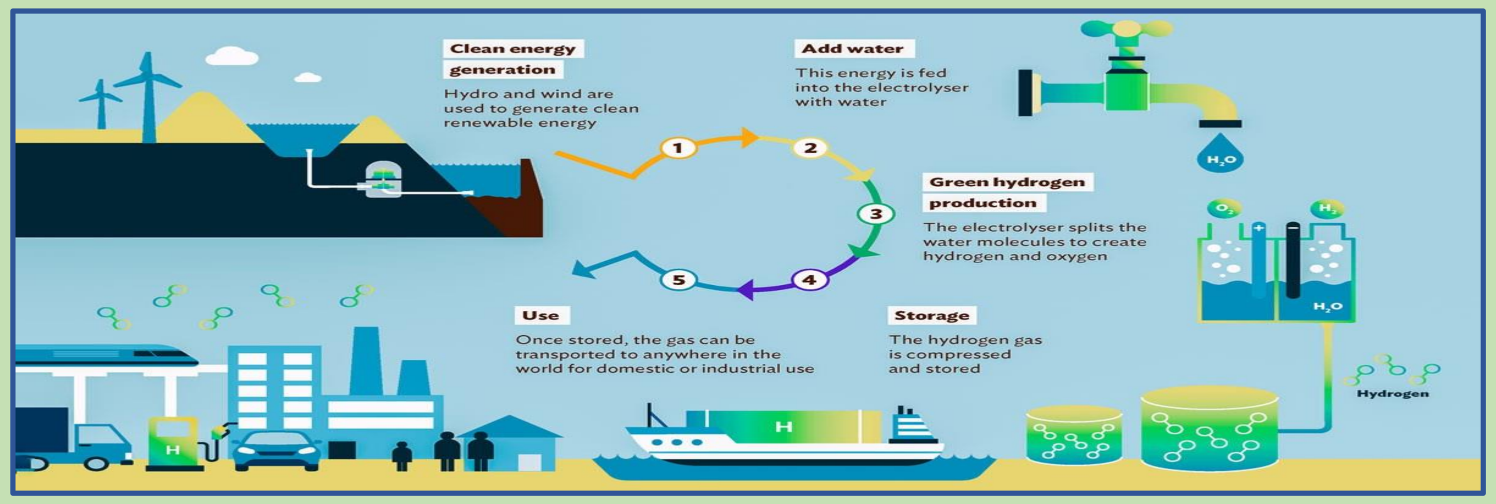

Figure 6: Green hydrogen production

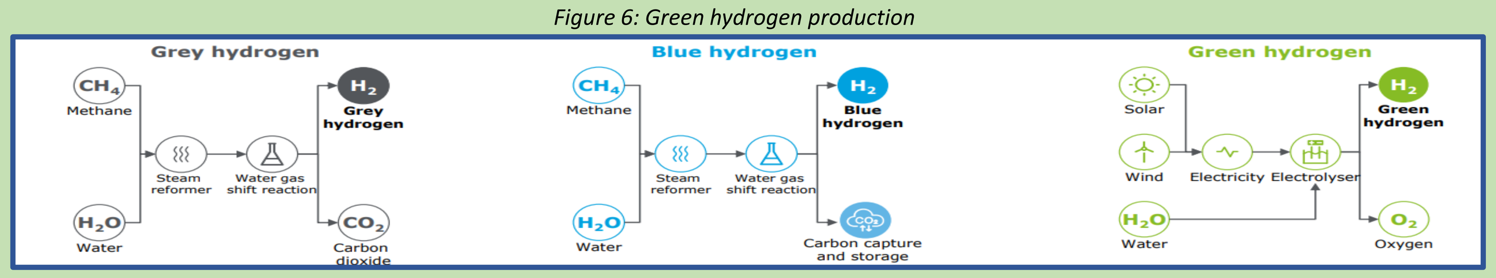

Figure 7: Hydrogen color spectrum

Hydrogen means "Creator (-gen) of water (hydro-)": its combustion release only **water**.

Global Hydrogen Adoption

Ceará, Brazil, and the Netherlands have established a Green Hydrogen Corridor between Pecém Port and the Port of Rotterdam, marking a significant step toward advancing green hydrogen adoption. This historic agreement, signed by the governor of Ceará and the Dutch Prime Minister, facilitates the transportation of green hydrogen to Europe, strengthening the collaboration between the two regions. The corridor is part of Ceará's ambition to become a global leader in green hydrogen production, with 30 memorandums of agreement already signed, including US$8 billion in investments.

Future Impact and Overcoming Challenges

Hydrogen is set to become a primary fuel source for global ports by 2050, with the potential to reduce maritime emissions by up to 80%. However, the shift faces challenges such as high infrastructure costs, safety concerns, and a lack of standardized regulations. To overcome these, governments are stepping in with financial support and policy initiatives. The EU Green Deal aims to make Europe the first climate-neutral continent by 2050, with specific measures to boost clean hydrogen production and infrastructure. In the U.S., initiatives like the Hydrogen Shot under the Department of Energy aim to reduce hydrogen production costs by 80% over the next decade, while states like California are providing incentives for green hydrogen projects. The Port of Houston recently received a $25 million grant from the U.S. Department of Transportation to develop hydrogen fueling infrastructure. The project, named 'Bayport HRS,' will create a publicly accessible hydrogen refueling station at the Bayport terminal, supporting the port's efforts toward sustainable operations and clean energy adoption.

Interview

"Hydrogen is not just a future possibility—it's a necessity for decarbonization and energy resilience. To advance it, we must prioritize infrastructure development, cost reduction, and widespread adoption across industries. The work being done today will define the energy landscape of tomorrow, and collaboration across governments, industry, and innovators is key to making hydrogen a mainstream fuel source," said Cody Patrick, the Hydrogen Segment Manager at Nikkiso Pumps and Fueling Systems and Board member at United States Hydrogen Alliance.

Economic Benefits

Hydrogen is expected to become cost-competitive with fossil fuels by 2030, offering significant savings in fuel and operational costs. The maritime sector could benefit from hydrogen technologies that reduce long-term fuel and maintenance expenses. Additionally, these technologies could create new revenue streams. This shift could unlock $1.4 trillion in value by 2050, generating green jobs and driving economic growth through more sustainable practices. Companies adopting hydrogen could access carbon credits and environmental incentives, avoiding penalties from stricter regulations. Nations and companies leading in hydrogen innovation will gain a competitive edge, fostering global partnerships and boosting trade opportunities.

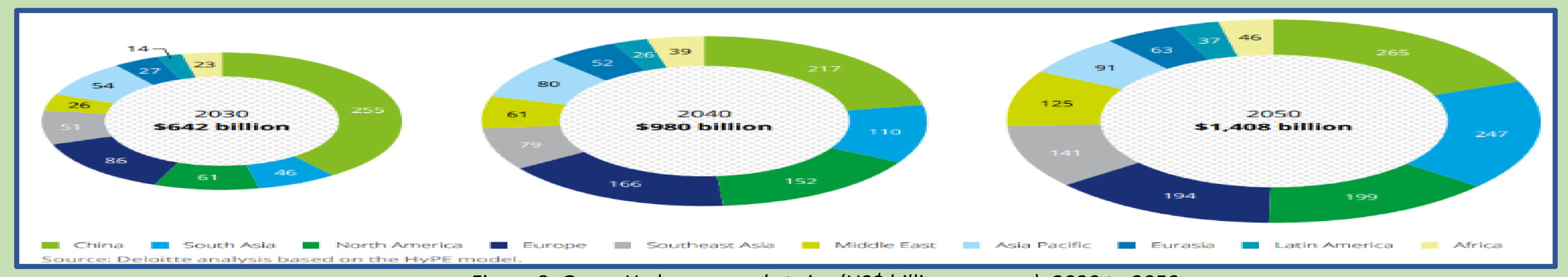

Figure 8: Green Hydrogen market size (US$ billion per year), 2030 to 2050.

Conclusion

Green hydrogen is a sustainable, zero-emission fuel for ports, offering environmental and economic benefits. Despite infrastructure challenges, technological advancements and policy progress are accelerating adoption. Investing in green hydrogen helps ports meet emissions regulations, improve energy security, and prepare for the future. This investment contributes to a cleaner maritime industry, with the goal of achieving zero emissions by 2050.

Scan Me: Citations, Biography, Video

Green Hydrogen Power:
Revolutionizing Port Operations for a Zero-Emission Future

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