



Green Hydrogen Diplomacy: Reshaping the Algeria-EU Energy Supply Chain in the Era of Decarbonization

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Abstract ;

The decarbonization drive positions green hydrogen as key to future energy. For hydrocarbon-reliant Algeria, this is both a challenge and a chance to redefine its EU energy partnership. This analysis argues that successful "Green Hydrogen Diplomacy" requires more than infrastructure; it demands institutional alignment, regulatory harmony, and risk mitigation to transform a traditional supply chain into a resilient, co-evolved green value chain

Article info

Received

21/01/2026

Accepted

15/03/2026

Keyword:

- ✓ Green Hydrogen
- ✓ Institutional Theory
- ✓ Supply Chain Management

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1. Introduction

The contemporary global energy landscape is undergoing a "Great Realignment," a tectonic shift driven by the dual pressures of an accelerating climate crisis and a radically altered geopolitical map. Since the onset of the conflict in Ukraine, energy security—once a quiet pillar of European industrial policy—has become an urgent survival mandate. The European Union's ambitious *REPowerEU* plan represents a historic pivot, aiming to import 10 million tonnes of renewable hydrogen by 2030. This strategy is not merely an environmental target; it is a calculated effort to decouple the European industrial base from its historical reliance on Russian fossil fuels while simultaneously propelling the European Green Deal toward its 2050 net-zero goals. In this context, the Mediterranean basin is emerging as the world's most critical theater for "Energy Diplomacy," a field where management science, international law, and economics converge to manage the risks of the transition.

Algeria, endowed with the world's tenth-largest proven natural gas reserves and a solar potential that exceeds its fossil energy capacity by several orders of magnitude (Sonatrach, 2023), finds itself at a historical and economic crossroads. For decades, the Algerian economy has functioned as a quintessential rentier state, where the export of crude oil and natural gas accounts for over 90% of export revenues and a substantial portion of the national budget. However, the introduction of the EU's Carbon Border Adjustment Mechanism (CBAM) and the rapid decline in the global "Social License to Operate" for fossil fuel majors pose a systemic risk to this model. To survive this "Green Disruption," Algeria must transition from being a producer of molecules to a manager of integrated green value chains.

This article contends that the shift toward green hydrogen (GH₂) is not merely a technical energy transition or an engineering feat; it is a profound restructuring of the Algeria-EU energy supply chain. Historically, this relationship has been characterized by a "buyer-seller" transactional logic. This legacy model was built on long-term, fixed-price contracts for natural gas, where Sonatrach served as a distant upstream supplier. In contrast, the GH₂ era demands a "partnership-based" management approach. This new paradigm necessitates deep organizational integration, involving multi-billion dollar co-investments in PEM and alkaline electrolyzers, large-scale seawater desalination plants, and the technologically complex task of repurposing existing cross-border pipeline infrastructure like the Transmed and Medgaz lines.

Despite the burgeoning literature on the technical feasibility of hydrogen production and transport, there remains a significant research gap regarding the management and diplomatic nexus required to facilitate this trade across different institutional environments. Most existing studies adopt a purely techno-economic perspective, overlooking how the

institutional frameworks and corporate governance structures in emerging economies like Algeria interact with the increasingly rigid ESG (Environmental, Social, and Governance) standards and "Additionality" rules of the EU. The objective of this paper is to analyze the economic and managerial determinants of this nascent supply chain, evaluating the competitiveness of Algerian GH2 through the lens of Porter's Diamond and Institutional Theory. It seeks to answer a critical strategic question: how can Algeria leverage its geographical and infrastructural proximity to the EU to avoid the structural pitfalls of the "resource curse" while becoming a vital, value-added node in the European hydrogen backbone?

2. Theoretical Background and Literature Review

2.1 Competitive Advantage and the Green Diamond: From Endowment to Strategy

Traditional economic theories of comparative advantage, most notably the Ricardian model (1817), posit that international trade is driven by differences in natural endowments. Under this static framework, Algeria is naturally positioned as an energy exporter due to its "basic factor" abundance—sun, wind, and land. However, Porter (1990) revolutionized this perspective by arguing that a nation's wealth is not inherited but created through a dynamic system known as the "National Diamond." This model consists of four mutually reinforcing poles: factor conditions; demand conditions; related and supporting industries; and firm strategy, structure, and rivalry. In the context of the green hydrogen (GH2) transition, the application of Porter's Diamond reveals a critical evolutionary path for Algeria.

Factor Conditions: Transitioning from Basic to Advanced Factors Algeria's "basic factors" are arguably the most competitive in the Mediterranean region. With Saharan solar irradiation averaging 2,500 kWh/m²/year and vast tracts of non-arable land, the physical capacity for renewable energy generation is unmatched (IRENA, 2022). Yet, Porter differentiates between basic factors and "advanced factors," such as specialized technical personnel, advanced R&D infrastructure, and digital energy management systems. This article argues that Algeria's current reliance on basic factors is a strategic vulnerability. To achieve a sustainable competitive advantage, management must prioritize the creation of advanced factors through specialized training programs for "Hydrogen Engineers" and the digitalization of the national grid.

Demand Conditions: The Sophistication of the Green Market The "demand conditions" pole in Porter's model suggests that nations gain a competitive advantage when domestic buyers are sophisticated and pressure companies to innovate. Currently, the demand for Algerian

GH2 is external and located in the EU's heavy industrial clusters. This creates a "demand-side dependency." For a resilient diamond to form, Algeria must stimulate "Sophisticated Domestic Demand." By mandating the use of GH2 in domestic steel production (AQS Bellara) or the fertilizer industry (Fertial), Algeria can create a domestic proving ground for its hydrogen technologies, reducing its exposure to international price shocks and carbon border taxes.

Related and Supporting Industries: The Cluster Effect A competitive diamond requires a localized "industrial cluster." In the GH2 value chain, this includes seawater desalination, chemical engineering, membrane manufacturing, and cryogenic logistics. Without a robust local ecosystem of "supporting industries," Sonatrach will be forced to import high-value equipment (electrolyzers, compressors), leading to significant "capital leakage." This article posits that the development of a "Mediterranean Green Energy Cluster"—where local SMEs provide maintenance and specialized components for electrolyzer plants—is the only way to avoid the historical pitfalls of the oil and gas "Enclave Economy" (Sachs & Warner, 2001).

Firm Strategy, Structure, and Rivalry The final pole concerns how companies are managed and the intensity of domestic rivalry. Historically, the Algerian energy sector has been dominated by Sonatrach, a state-owned monopoly. While this structure allows for massive capital mobilization, it often lacks the efficiency-driven innovation that stems from domestic rivalry. This paper argues that the transition to GH2 necessitates a shift in "firm strategy." Algeria must move toward a more pluralistic market structure, encouraging Public-Private Partnerships (PPPs) and allowing for smaller, agile energy "start-ups" to coexist with the national champion. This internal competition is essential to drive down the Levelized Cost of Hydrogen (LCOH) and meet the rigorous efficiency benchmarks set by the global market.

Without this holistic "clustering" effect, Algeria risks remaining a mere exporter of cheap molecules, repeating the "resource curse" patterns of the fossil fuel era where high-value industrial activities remain concentrated in the Global North.

2.2 Institutional Economics and the Rentier State Dilemma: Navigating Path Dependency

Institutional economics provides a critical lens through which to view the challenges of energy-rich developing nations. North (1990) famously posited that institutions are the "rules of the game" that provide the incentive structure of an economy. In the case of Algeria, the historical institutional framework has been forged by decades of reliance on fossil fuel rents, creating a quintessential "rentier state." In such an environment, institutions are often optimized for "extractive efficiency"—the ability of the state to capture and redistribute

resource rents—rather than for innovation, entrepreneurship, or competitive market dynamics.

The Barrier of Path Dependency A primary institutional challenge identified in this article is "Path Dependency" (Arthur, 1994). The Algerian energy bureaucracy, centered on Sonatrach and the Ministry of Energy, has developed specialized knowledge, legal procedures, and administrative habits specifically tailored to the liquid and gaseous hydrocarbon sectors. This historical legacy creates an "institutional lock-in," where the transition to a renewable energy carrier like green hydrogen is viewed through the lens of traditional gas management. For example, current regulatory frameworks for energy exploration and production often fail to account for the unique decentralized and manufacturing-intensive nature of green hydrogen production. To break this cycle, Algeria must implement "Institutional Unlearning," deconstructing old bureaucratic hurdles that favor fossil fuels and replacing them with agile, "Hydrogen-First" regulatory pathways.

Institutional Isomorphism and Regulatory Convergence As Algeria seeks to integrate into the European hydrogen backbone, it faces a process of *Institutional Isomorphism* (DiMaggio & Powell, 1983). This phenomenon describes the tendency of organizations in a shared field to mirror one another's structures. For Algerian hydrogen to be bankable in Europe, Algerian regulatory bodies must achieve a high degree of "Regulatory Convergence" with EU standards, particularly regarding the EU Taxonomy and the Renewable Energy Directive (RED II). This is not merely a technical requirement; it is a diplomatic and managerial necessity. Without institutions that can guarantee "Certification of Origin" and audit environmental additionality to European standards, Algerian green hydrogen will suffer from a "Legitimacy Discount," remaining excluded from the high-premium European market.

The Green Dutch Disease and the Quality of Government Furthermore, the article argues that the transition to green hydrogen could inadvertently trigger a "Green Dutch Disease." Sachs and Warner (2001, p. 828) described how traditional resource booms can weaken the broader economy by overvaluing the currency and crowding out manufacturing. In the green transition, a sudden influx of foreign direct investment (FDI) into massive hydrogen projects could lead to similar inflationary pressures. Institutional economics suggests that the "Quality of Government" (QoG)—transparency, the rule of law, and the absence of corruption—is the primary variable that determines whether a resource boom becomes a blessing or a curse. Algeria's ability to manage hydrogen revenues through an independent Sovereign Wealth Fund, decoupled from the volatile national budget, will be the ultimate test of its institutional maturity.

Reforming the Social Contract Finally, the "Rentier State Dilemma" extends to the social contract. Rentier states often rely on "Distributional Institutions" to maintain social peace through subsidies and public sector employment. The green hydrogen sector, being highly capital-intensive but potentially less labor-intensive than traditional oil and gas in terms of unskilled labor, may not fit easily into this old distributional model. This research posits that Algerian management must reform its "Institutional Social Contract," shifting from a model of rent redistribution to one of "Productive Inclusion," where the hydrogen sector fuels a broader industrialization that creates sustainable private-sector employment.

2.3. Strategic Management and Supply Chain Integration (SCI)

From a management perspective, the GH2 supply chain is fundamentally different from the natural gas chain. Natural gas is an extracted commodity; green hydrogen is a *manufactured* energy carrier. This requires a much higher degree of "Supply Chain Integration" (SCI). For Algeria to be successful, Sonatrach must move beyond its role as a "well-head supplier" and become a "vertical integrator." This involves aligning with European off-takers (e.g., ThyssenKrupp or BASF) on technical standards, pressure requirements, and purity levels. This alignment is not just technical; it is a managerial challenge involving joint R&D and shared risk-reward mechanisms.

2.4. Geopolitical Economy and "Energy Justice"

Hydrogen diplomacy is an emerging subfield of international political economy. Scholten and Bosman (2016) suggest that the shift to renewables will redraw the maps of global power. However, critical social scientists point to the risk of "Green Neocolonialism," where resources are extracted for the Global North while the Global South bears the environmental costs (e.g., brine from desalination). This article incorporates an "Energy Justice" framework, arguing that the Algeria-EU partnership must be predicated on local value creation and community participation in the High Plateaus and Saharan regions.

3. Methodology: A Multi-Dimensional Analytical Framework

This article adopts a qualitative and analytical methodology, meticulously integrating supply chain management (SCM) principles with macroeconomic forecasting and institutional analysis. Given the nascent and highly volatile nature of the global hydrogen market, a purely quantitative approach is insufficient; therefore, we utilize a "Value Chain Mapping" approach as our primary heuristic. This allows us to identify specific value-creation nodes and "value-leakage" points within the proposed Algeria-EU GH2 corridor. By triangulating data from industry reports, legislative texts, and economic models, the methodology seeks to provide a holistic view of the transition.

The Integrated Green Value Chain Model Our conceptual framework segments the GH2 supply chain into six strategic pillars, each representing a distinct managerial and economic hurdle:

1. **The Energy-Water Mix (Upstream):** This pillar focuses on the synergy between high-yield renewable energy (solar/wind) and seawater desalination. We analyze the "desalination energy penalty"—the 3-4 kWh of electricity required per cubic meter of water—and how its optimization determines the baseline cost of hydrogen.
2. **Conversion (Mid-Upstream):** This involves electrolysis management, specifically evaluating the trade-offs between Proton Exchange Membrane (PEM) and Alkaline technologies. We analyze these choices not just through technical efficiency, but through "Supply Chain Resilience," considering the rare-earth mineral dependencies of PEM stacks versus the mature, localized manufacturing potential of Alkaline electrolyzers.
3. **The Transport Corridor (Midstream):** We examine the economics of Levelized Cost of Transport (LCOT). This includes a granular analysis of the repurposing costs for the Transmed and Medgaz pipelines, accounting for hydrogen embrittlement risks in legacy steel and the cost-benefit ratio of dedicated hydrogen compressors.
4. **Offtake and Certification (Mid-Downstream):** This pillar addresses the "Regulatory Supply Chain." We analyze the management of "Additionality" rules under the EU's RED II, exploring how Algerian producers can navigate the temporal and geographic correlation requirements to ensure their product reaches the "Green" premium market.
5. **Industrial Integration (Downstream):** We move beyond the export-only model to evaluate the domestic "Value-Addition" multiplier. This includes a strategic analysis of using GH2 for "Green Steel" in Bellara or green ammonia in Arzew, quantifying how domestic industrialization hedges against fluctuations in international energy prices.
6. **Diplomatic Governance (Horizontal):** This pillar cross-cuts the entire chain, focusing on the bilateral treaties, sovereign guarantees, and regulatory harmonization required to "de-risk" multi-billion dollar CAPEX investments. It views diplomacy as a managerial tool for reducing the "Institutional Distance" between the two jurisdictions.

Data sources for this analysis include the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), World Bank macroeconomic profiles, and Sonatrach's internal strategic reports (2023-2024). By synthesizing these diverse inputs, the framework provides a predictive lens for the future of Mediterranean energy trade.

4. Results and Analytical Discussion

4.1. The Economics of Competitive Advantage: A Quantified View

For Algeria, the primary challenge is the Levelized Cost of Hydrogen (LCOH). By 2030, the EU's internal production cost is expected to remain high due to land constraints, lower solar yields, and higher labor costs.

Table 1: Comparative Factor Indicators (Real Statistics & 2024 Benchmarks)

Indicator	Algeria (Saharan Region)	Southern Europe (Spain/Italy)	Northern Europe (Germany)	Source
Solar Irradiance (kWh/m ²)	2,400 - 2,800	1,800 - 2,100	1,000 - 1,200	Solargis (2023)
Capacity Factor (%)	30% - 35%	18% - 22%	11% - 14%	IRENA (2024)
Est. LCOH 2030 (\$/kg)	\$1.60 - \$2.10	\$2.80 - \$3.50	\$4.20 - \$5.10	IEA (2023)
Pipeline Distance (km)	200 - 800	N/A	1,500+	Author Calc.
Potential GH2 Output (Mtpa)	2.5 (by 2040)	1.0 (by 2040)	0.4 (by 2040)	Sonatrach (2023)

Caption: Algeria's high capacity factor—averaging 30-35% due to superior Saharan solar irradiation—directly translates into a 50-60% lower LCOH compared to Northern Europe. This advantage is primarily driven by the ability to amortize the high CAPEX of electrolysis equipment over a greater number of operating hours per year. Even when a "Transport Premium" via repurposed pipeline infrastructure is added—averaging \$0.20 to \$0.45 per kg—the final landed cost of Algerian GH2 remains approximately 30-40% cheaper than the marginal cost of production in industrial hubs like the Ruhr Valley. This price gap provides a robust "Economic Buffer" that can absorb potential carbon taxes or regulatory compliance costs.

4.2. Infrastructure Management: The "Sunk Cost" Strategic Asset and the SouthH2 Corridor

In the economics of large-scale energy trade, the "Levelized Cost of Transport" (LCOT) often determines the feasibility of a supply chain. For Algeria, the most potent strategic weapon in its energy arsenal is not the sun, but its existing, world-class pipeline architecture. This infrastructure

represents a "Sunk Cost"—capital already invested and partially amortized through decades of natural gas exports—which can now be pivoted to serve the green economy.

The Economic Logic of Repurposing Building a new, 48-inch high-pressure hydrogen pipeline across the Mediterranean is an immense financial undertaking. Estimates from the Hydrogen Council (2022) put the CAPEX of new builds at approximately \$2.5 million to \$3.5 million per kilometer, excluding the geopolitical complexities of seabed surveying and territorial water permits. In contrast, repurposing existing gas pipelines, such as the Trans-Mediterranean (Transmed) line connecting Algeria to Italy via Tunisia, or the Medgaz line connecting directly to Spain, offers a radical cost advantage. Technical assessments suggest that repurposing—which involves internal polymer lining to prevent hydrogen embrittlement, upgrading compressor stations to handle lower molecular weights, and replacing specific valve assemblies—costs only 15% to 20% of a new construction project. This massive reduction in upfront capital allows Algerian GH₂ to reach the European market at a price point that maritime shipping of liquid hydrogen or ammonia cannot match.

The SouthH₂ Corridor: A Case Study in Management Integration The centerpiece of this infrastructure strategy is the "SouthH₂ Corridor." This planned 3,300 km "hydrogen backbone" aims to connect North Africa to Germany's industrial heartland via Italy and Austria. The project is a masterpiece of multi-national managerial integration, involving transmission system operators (TSOs) like Snam (Italy), TAG (Austria), and Bayernets (Germany). For Algeria, the SouthH₂ Corridor transforms the nation from a "peripheral supplier" into an "integral node" of the European energy grid.

However, managing this "Strategic Asset" involves complex cross-border challenges:

1. ***Technical Standardization:*** Hydrogen requires different compression ratios than natural gas. Managing the "Energy Density" of the flow necessitates real-time digital monitoring and a synchronized upgrade of compressor stations across four different national jurisdictions.
2. ***The "Blending" Phase:*** During the transition, pipelines will likely carry a blend of natural gas and hydrogen (up to 20%). This requires sophisticated "de-blending" technologies at industrial off-take points in Italy and Austria to ensure high-purity hydrogen reaches end-users.
3. ***Institutional Interoperability:*** The SouthH₂ project is designated as a Project of Common Interest (PCI) by the EU, providing access to accelerated permitting and "Connecting Europe Facility" (CEF) funding. Algeria must align its domestic regulatory timelines with these European "fast-track" mechanisms to avoid becoming a bottleneck in the corridor.

Geopolitical and Legal Sovereignty From a political science perspective, the Transmed pipeline introduces a "Transit Risk" management variable. Since the pipe traverses Tunisian territory, the Algeria-EU relationship becomes a trilateral one. Diplomacy here serves as a "Midstream Management" tool, ensuring that transit fees and security protocols are harmonized to prevent supply disruptions. This article argues that the "Sunk Cost" advantage is only real if the diplomatic framework surrounding the pipe is as resilient as the steel itself.

4.3. *The Water-Energy-Food (WEF) Nexus: A Management Challenge*

A critical, often overlooked, management variable in GH2 production is water. Producing 1 kg of hydrogen requires roughly 9-11 liters of high-purity water. For Algeria, an arid nation facing chronic water stress, using freshwater or fossil aquifers for hydrogen export is politically and ethically untenable.

The management strategy must therefore be one of "Desalination-Plus." Algeria is currently investing in 11 new desalination plants to reach a capacity of 3.7 million m³/day by 2030. Integrating these with solar-powered electrolyzers allows for "Zero-Carbon Water." From a public policy perspective, this creates a "Social License to Operate" (SLO). If the desalination plants also provide excess water for local Saharan agriculture (Greenhouses), the hydrogen industry becomes a tool for regional development and food security, not just energy export.

4.4. *The Technological Choice: PEM vs. Alkaline*

In the mid-upstream segment, Algerian management faces a choice between Alkaline (mature, cheaper) and PEM (more flexible, suited for variable renewable energy) electrolyzers. While Alkaline is currently more cost-effective for large-scale steady-state production, PEM's ability to "follow" the solar curve without a battery buffer makes it ideal for the Saharan context. We argue that a "Hybrid Portfolio" approach is necessary: using Alkaline for baseload production coupled with massive solar farms, and PEM for smaller, more isolated wind-solar clusters.

4.5. *Regulatory Barriers and the "Additionality" Debate*

The EU's RED II (Renewable Energy Directive) Delegated Acts require that renewable electricity used for "green" hydrogen must be "additional"—meaning it cannot come from existing renewable assets that already serve the grid. For Algeria, where 99% of electricity is currently gas-fired, this is a massive barrier.

This article argues that Algeria should adopt a "Bifurcated Management Model":

1. **The Export Hub:** Off-grid, massive solar-wind farms in the Adrar region dedicated solely to hydrogen export to meet EU "Additionality" standards.
2. **The Domestic Transition:** "Blue" hydrogen produced via Steam Methane Reforming (SMR) with Carbon Capture and Storage (CCS) to decarbonize domestic industry (fertilizers, cement) as a lower-cost intermediate step while the green grid is being built.

5. *Discussion: Reshaping the Diplomatic and Economic Narrative*

5.1. *Breaking the Rentier Cycle: From Commodities to Value Chains*

Historically, the Algeria-EU energy relationship has been "extractivist." Algeria exported the molecule; Europe captured the industrial value. Green hydrogen offers a chance to break this cycle through "Green Industrialization." By using cheap GH2 domestically, Algeria can produce "Green Steel" or "Green Cement" which would be exempt from the EU's Carbon Border Adjustment Mechanism (CBAM). This would shift the Algerian economy from a "Price Taker" in energy markets to a "Value Creator" in industrial markets.

5.2. Geopolitical Risks: The Mediterranean "Race to the Top"

Algeria is not alone in its hydrogen ambitions. Morocco (with superior wind potential and deep EU political integration) and Egypt (with the Suez Canal logistics hub) are formidable competitors. Algeria's competitive edge remains its pipeline connectivity. However, institutional "Red Tape" remains a major deterrent for EU investors. A comparison of "Ease of Doing Business" in the energy sector shows that Algeria must streamline its bureaucracy to match the "Hydrogen Task Forces" established by its neighbors.

Table 2: SWOT Analysis of the Algeria-EU GH2 Partnership (Weighted Factors)

Strategic Factor	Weight	Score (1-10)	Description
Strength: Pipeline Infrastructure	0.25	9	Existing Medgaz/Transmed provides direct access to EU.
Strength: Solar Factor	0.20	10	Highest irradiation capacity factors in the region.
Weakness: Institutional Rigidity	0.15	4	Slow permitting and bureaucratic "bottlenecks."
Opportunity: EU CBAM	0.20	8	CBAM makes non-green imports expensive; GH2 is the cure.
Threat: Water Scarcity	0.10	5	Desalination costs may impact final LCOH competitiveness.
Threat: Regional Comp.	0.10	7	Morocco/Egypt are aggressive on FDI attraction.

Caption: The weighted analysis suggests that while Algeria's natural and infrastructural strengths are overwhelming, institutional weakness is the primary "drag" on strategic success.

5.3. Financial Management and Risk Mitigation

The investment requirements are staggering. A 10 GW green hydrogen plant requires roughly \$20 billion in CAPEX. For a country with limited access to international capital markets, this requires "De-risking" mechanisms. We propose the use of "Green Bonds" backed by the African Development Bank and "Contracts for Difference" (CfD) where the EU guarantees a minimum purchase price for Algerian GH2 for the first 15 years.

Table 3: Financial Projection for a 5GW Integrated GH2 Project (Hypothetical Illustrative Data)

Phase	Investment (\$bn)	Capacity	Payback Period	Est. IRR
Phase I: Pilot (2025-2027)	1.8	500 MW	12 Years	6.5%
Phase II: Scaling (2028-2035)	8.5	2.5 GW	9 Years	11.0%
Phase III: Export (2036-2045)	22.0	10.0 GW	7 Years	14.5%

Caption: As technology matures and the cost of electrolyzers drops (Wright's Law), the Internal Rate of Return (IRR) is expected to rise, making private-sector financing more attractive than sovereign debt.

5.4. Institutional Reform: The "Law of the Sun"

The 2019 Hydrocarbon Law, while a step forward, remains tethered to the fossil fuel paradigm. This article proposes a "Unified Energy Code" that treats solar energy as a strategic national resource similar to oil. This would allow for "Direct Power Purchase Agreements" (PPAs) between foreign developers and the national utility (Sonelgaz), bypassing the current institutional bottlenecks and allowing for "Off-Grid" export clusters.

6. Conclusion and Strategic Implications

6.1. Summary of Findings

This study has demonstrated that the transition to green hydrogen is the most significant strategic opportunity for Algeria since the discovery of Hassi Messaoud. The economic fundamentals—solar yields, land availability, and pipeline proximity—are exceptionally strong. However, the realization of this potential is not a technical problem but a managerial and institutional one. The "Sunk Cost Advantage" of existing pipelines must be leveraged through diplomatic "Hydrogen Corridors" that align Algerian supply with European industrial demand.

6.2. Theoretical Implications

The paper expands Porter's Diamond by introducing the "Green Factor"—where sustainability becomes a source of competitive advantage rather than a cost. It also contributes to Institutional Theory by showing how "Institutional Distance" between the EU and Algeria must be closed through regulatory convergence to allow for deep supply chain integration.

6.3. Policy and Managerial Recommendations

- 1. For the Algerian Government:** Establish a "National Hydrogen Agency" with the authority to fast-track permits and manage international tenders. Separate hydrogen revenues into a "Green Transition Fund" dedicated to domestic industrialization and Saharan desalination.

2. **For Sonatrach:** Evolve from a "National Oil Company" (NOC) to an "Integrated Energy Giant." This requires massive investment in digital supply chain management, ESG reporting, and "International Joint Ventures" with EU industrial majors.
3. **For the EU:** Recognize Algeria as a "Strategic Energy Partner" rather than just a supplier. This involves providing technical assistance for the "Green Hydrogen Backbone" and including Algeria in the "European Hydrogen Bank" auctions.

6.4. Limitations and Future Research

This research is limited by the current volatility of global hydrogen prices and the lack of large-scale operational data from North Africa. Future studies should focus on the "Socio-Economic Multiplier" of hydrogen—specifically how many local jobs are created per megawatt of installed capacity—and the environmental impact of brine disposal from desalination on Saharan ecosystems. Furthermore, the role of "Blue Hydrogen" as a transitional tool requires more empirical modeling of Carbon Capture and Storage (CCS) costs in the Algerian geological context.

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