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EVALUATING THE PROFITABILITY OF HYDROGEN AND AMMONIA PRODUCTION IN BRAZIL: STRATEGIC INVESTMENT INSIGHTS

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ABSTRACT

This thesis evaluates the financial feasibility and profitability of constructing an integrated hydrogen and ammonia production facility in Brazil. Using a mixed methods approach, it combines primary insights from expert interviews with quantitative capital investment modelling and international benchmarking. The research addresses the profitability of such a project depends on the balance between capital costs, operational expenses, and revenue streams. It employs financial metrics such as Levelized Cost of Hydrogen (LCOH), Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period to assess economic viability. The findings indicate a competitive LCOH of $2.10/kg and a robust NPV of $228 million over a 20 year horizon, with a payback period of 4.36 years and IRR of 23%. These results position Brazil as a cost effective location for green hydrogen and ammonia production, supported by its abundant renewable resources and growing market opportunities. This research provides actionable investment insights and contributes to the strategic planning necessary for Brazil to emerge as a leader in the global hydrogen economy.

Keywords: Hydrogen, Ammonia, Capital Investment, Profitability, LCOH, NPV, IRR, and Brazil

INTRODUCTION

1.1 Background

1.1.1 Hydrogen's Role in the Global Energy Transition

Hydrogen has emerged as a critical component of the global strategy to decarbonize economies and reach net zero emissions. Its unique properties being a clean, energy dense, and versatile fuel make it suitable for sectors that are traditionally hard to abate, such as long distance transport, industrial processes, and power generation. As nations strive to reduce reliance on fossil fuels, hydrogen offers a pathway that complements renewable electricity by providing long duration storage, sector coupling, and fuel switching capabilities. One of the most compelling advantages of hydrogen is its ability to store energy across time and geography. Unlike batteries, which are suitable for short term energy storage, hydrogen can be stored over long periods and transported through pipelines or ships. This makes it a strategic asset for managing energy supply with demand mismatches and ensuring energy security, especially in regions with variable renewable energy availability *Impact Economist (2025)*. Hydrogen's versatility has placed it at the forefront of discussions on achieving net zero emissions. Hydrogen can decarbonize sectors that are challenging to electrify directly, such as heavy transportation (aviation and shipping), industrial manufacturing (steel and cement), and high temperature heat processes. Green hydrogen, derived from renewable energy sources via water electrolysis, offers the cleanest pathway to large scale energy transition. Emerging markets in Europe, East Asia, and North America have already prioritized hydrogen in their energy roadmaps. For instance, the European Union's "Hydrogen Strategy for a Climate Neutral Europe" envisions up to 40 GW of green hydrogen electrolysers by 2030 *Clifford Chance (2020)*. Similarly, Japan and South Korea have committed billions of dollars to hydrogen technology innovation, storage, and supply chains. These initiatives highlight the growing global demand for hydrogen production and underscore the need for competitive production costs to meet this demand *Morgan Lewis (2023)*.

1.1.2 Brazil's Energy Landscape

Brazil, with its vast renewable energy potential, stands out as a promising location for large scale hydrogen production. The country's renewable energy matrix, dominated by hydroelectric power, is increasingly complemented by expanding wind and solar capacities. These resources can provide the clean electricity required for producing green hydrogen via electrolysis. Moreover, Brazil's geographical position offers logistical advantages, enabling it to supply both domestic and international markets efficiently. By combining these factors, Brazil has the opportunity to emerge as a leader in the global hydrogen economy. Brazil's energy matrix is predominantly renewable, with hydropower providing over 60% of the electricity generation and wind and solar energy expanding rapidly. This renewable dominance positions Brazil as a prime candidate for green hydrogen production. By capitalizing on its natural resources, Brazil can develop a cost effective green hydrogen supply chain and export to regions with constrained renewable resources but high demand for clean hydrogen. However, Brazil's domestic hydrogen ecosystem remains in its infancy. Current efforts are fragmented, with limited large scale production infrastructure.

Government policies supporting hydrogen production, although nascent, signal growing interest in positioning Brazil as a major player in the global hydrogen economy *Reglobal (2024)*. Brazil holds a unique position in the global sustainability landscape due to its abundant natural resources, clean energy mix, and strategic potential in green fuel production. According to a *McKinsey & Company (2023)* report, the country's emissions profile is distinct, with nearly 50% stemming from deforestation and land use changes, followed by emissions from agriculture and the energy sector. With one of the world's cleanest electricity grids supported by hydro, wind, and solar Brazil is well positioned to become a major player in the green hydrogen and ammonia markets. The report estimates that domestic demand could absorb around 60% of green hydrogen supply by 2040, while export markets for green fuels could represent up to $20 billion annually. In parallel, Brazil's capacity for sustainable biomass production and a rapidly growing carbon credit market further enhance its economic viability in the low carbon transition.

1.1.3 The Role of Hydrogen in Ammonia Production

Ammonia, a key derivative of hydrogen, is essential in agriculture (as a fertilizer) and shipping (as a zero emission fuel). Traditional ammonia synthesis relies on fossil fuel based hydrogen (grey hydrogen), contributing significantly to global CO_2 emissions *Pavlenko (2023)*. Transitioning to green ammonia production represents a critical opportunity to decarbonize agriculture and support the shipping industry's shift to cleaner fuels. Brazil, as one of the world's largest agricultural exporters, can use green ammonia to enhance sustainable practices in its domestic fertilizer market while tapping into growing international demand *McKinsey and Company (2023)*.

1.1.4 Importance of Investigating Capital Investment Costs

According to *OECD (2023)*, Investigating the capital investment costs of hydrogen production facilities is crucial for multiple reasons, particularly in assessing the feasibility and scalability of green hydrogen projects. First and foremost, understanding the cost structure allows for a thorough evaluation of whether hydrogen production is economically viable. Given the substantial upfront investment required for building electrolysis plants, renewable energy infrastructure, and storage systems, it is essential to determine if these projects can generate sufficient returns to justify such investments. A detailed analysis of capital investment costs provides a clearer picture of the financial dynamics involved, including how long it might take for these projects to become profitable and what their long term sustainability will look like. This insight is invaluable for investors, energy developers, and policymakers, as they must evaluate whether the financial risks and rewards associated with green hydrogen production align with their objectives. Moreover, the scalability of hydrogen production is another key consideration that stems from understanding the capital investment requirements *Curcio (2025)*. Large scale production facilities are essential for achieving economies of scale, which help reduce the cost per unit of hydrogen produced. In countries like Brazil, where renewable resources such as hydro, wind, and solar energy are abundant, scaling production can significantly improve competitiveness on the global stage. Understanding the capital requirements for scaling up operations enables stakeholders to better anticipate the long term infrastructure investments needed to build a sustainable hydrogen economy that can meet both domestic and international demand. For Brazil, with its vast renewable energy potential, scalability becomes even more important because it can position the country as a key exporter of green hydrogen. This requires a clear understanding of the capital investment needed not just for initial production but also for expansion to accommodate growing demand in international markets. The viability of Brazil's hydrogen industry will depend largely on how well it can scale production while managing capital investment costs, ensuring that it can keep up with global demand and maintain competitiveness in the hydrogen market. Therefore, investigating these costs is central to making informed decisions about the country's future role in the global hydrogen economy *Oliveros (2023)*.

1.2 Problem Description

1.2.1 Capital Investments as a Barrier

According to *IRENA (2022)*, that renewable ammonia production projects often entail substantial capital expenditures. Specifically, for integrated renewable ammonia plants, the hydrogen, nitrogen, and ammonia production units themselves may represent less than 50% of the total cost, with the majority invested in upstream development for renewable electricity generation. The capital intensity for the largest announced renewable ammonia plants (including electricity generation) to start operation beyond 2030 is projected to decrease from around USD 4,800 per tonne annually at a capacity of 0.5 million tonnes of ammonia per year, to around USD 3,000 per tonne annually at a capacity of 10 million tonnes per year. This underscores the significant upfront investments required for such facilities.

1.2.1.1 Brazil's Investment in Hydrogen Based Ammonia Facilities

GoVerde Energia's recent initiative in Brazil exemplifies the substantial investments needed for hydrogen and ammonia production. The company plans to invest approximately BRL 5.4 billion (USD 949 million) into developing a hydrogen based methanol and ammonia production facility in Bahia state. This investment reflects the high capital requirements for establishing such integrated facilities in developing countries *H2 View (2025)*.

1.2.1.2 Challenges in Developing a Sustainable Hydrogen Economy in Brazil

A report by the Sabin Centre for Climate Change Law at Columbia Law School discusses the hurdles Brazil faces in establishing a sustainable hydrogen economy. It notes that hydrogen is primarily used for ammonia synthesis, methanol production, and petroleum refining in Brazil. The report emphasizes that the development of hydrogen infrastructure, including electrolysers and storage units, involves significant upfront investments, posing substantial barriers to entry for the country *Colombia Climate School (2023)*.

1.3 Research Questions

This thesis is driven by the following key research question:

1. What is the estimated profitability of constructing a hydrogen production and storage facility in Brazil, considering factors such as capital investment, operating costs, and revenue potential and how does this profitability compare to benchmarks from similar projects in the global hydrogen industry?

To address this primary question, the study will also explore the following sub-questions:

1. What are the main cost components involved in the construction and operation of a hydrogen production facility integrated with ammonia synthesis?
2. How do geographic, economic, and technological factors influence the profitability potential of hydrogen production projects in Brazil?

1.4 Research Objectives

The overarching objective of this research is to provide a comprehensive analysis of the capital investment requirements for a hydrogen production and storage facility in Brazil. This objective is divided into several specific goals:

1. Estimate Capital Investment Costs: Develop a detailed breakdown of the costs involved in constructing the facility, including equipment, infrastructure, and operational setup.
2. Benchmark Against Similar Projects: Compare the estimated costs with data from similar hydrogen and ammonia production projects globally to identify trends, outliers, and best practices.
3. Identify Key Cost Drivers: Analyse the factors that most significantly influence capital investment requirements, such as technology choices, production scale, and local market conditions.
4. Provide Strategic Recommendations: Offer actionable insights for optimizing investment strategies and ensuring the project's competitiveness in the global hydrogen market.

1.5 Significance of the Study

This research addresses a critical gap in knowledge at the intersection of energy transition and economic planning. As hydrogen gains momentum as a clean energy solution, understanding the financial and strategic aspects of developing production facilities becomes essential. For Brazil, this study provides a roadmap for harnessing its natural advantages and aligning with global trends in renewable energy development. Additionally, the findings of this thesis have broader implications for the hydrogen industry. By examining cost structures and benchmarks, this research contributes to the growing body of literature on hydrogen economics and infrastructure development. It highlights the interplay between technical feasibility, financial viability, and market dynamics, offering valuable insights for policymakers, investors, and industry leaders worldwide.

The establishment of a hydrogen and ammonia production facility in Brazil represents a significant opportunity to advance the country's energy transition while contributing to the global clean energy agenda. However, the success of this endeavour depends on a clear understanding of the capital investment required and its alignment with international benchmarks. By addressing these challenges, this thesis aims to support informed decision-making and strategic planning, ensuring that Brazil maximizes its potential as a leader in the emerging hydrogen economy.

METHODOLOGY

2.1 Literature Review Methodology

2.1.1 Hydrogen Production Technologies

Hydrogen production methods are categorized into three primary types:

- Grey Hydrogen: Derived from natural gas via steam methane reforming (SMR), emitting significant CO_2.
- Blue Hydrogen: Similar to grey hydrogen but incorporates carbon capture and storage (CCS) to reduce emissions.
- Green Hydrogen: Produced through water electrolysis using electricity from renewable sources, achieving near zero emissions.

Several studies emphasize the importance of transitioning from grey and blue hydrogen to green hydrogen to meet decarbonization goals. A report by the International Renewable Energy

Agency *IRENA (2022)* highlights the decreasing costs of electrolysers and renewable energy as key enablers for green hydrogen competitiveness. However, challenges such as high capital costs and the scalability of electrolysis technologies persist.

2.1.2 Economic Analysis of Hydrogen Projects

The economic feasibility of hydrogen projects depends heavily on capital investment, operational costs, and market factors. The Levelized Cost of Hydrogen (LCOH) is a widely used metric for assessing the competitiveness of hydrogen production technologies. Studies such as those by *BNEF (2021)* project that LCOH for green hydrogen will fall below $2/kg by 2030 in regions with abundant renewables, making it cost competitive with blue hydrogen. Brazil specific studies, although limited, indicate promising LCOH potential due to the country's low cost renewable energy resources. However, gaps in localized data on capital investments, including costs for electrolysers, storage infrastructure, and ammonia synthesis units, hinder comprehensive economic assessments.

2.1.3 Benchmarking and International Case Studies

Benchmarking successful hydrogen production facilities offers valuable insights into cost structures and best practices. Projects such as the Hydrogen Energy Supply Chain (HESC) in Australia and the HyNet North West initiative in the UK provide models for integrating hydrogen production, storage, and distribution. Key lessons from these projects include the importance of scalable technologies, public private partnerships, and streamlined regulatory frameworks. Despite the availability of international benchmarks, their direct applicability to Brazil is limited by contextual differences, such as resource availability, labour costs, and policy environments. Literature exploring these regional nuances is critical to tailoring strategies for Brazil's unique conditions.

2.1.4 Ammonia Synthesis and Market Trends

Ammonia production accounts for a significant share of hydrogen demand, particularly in agriculture and shipping. The Haber Bosch process, used for ammonia synthesis, traditionally relies on fossil fuel based hydrogen. Transitioning to green ammonia requires integrating electrolysers with ammonia synthesis units, a process that involves substantial capital investments. Market studies *IEA (2023)* predict a growing demand for green ammonia, driven by sustainable agriculture initiatives and the adoption of ammonia as a marine fuel. However, achieving cost parity with conventional ammonia remains a challenge, particularly in regions with high infrastructure costs.

2.2 Gaps in the Literature

The review highlights several gaps in existing research:

1. Limited localized studies on capital investment requirements for hydrogen production in Brazil.
2. Insufficient analysis of cost drivers specific to Brazil's renewable energy landscape.
3. A lack of integrated studies on green hydrogen and ammonia production, focusing on both technical and economic aspects.

2.3 Data Research Methodology

2.3.1 Research Design

This study adopts a mixed methods approach, with a primary focus on evaluating project profitability. The research design is structured to:

1. Quantitatively assess the project's financial viability through capital investment modelling and cash flow analysis.
2. Compare profitability metrics such as LCOH, NPV, IRR, and payback period against international hydrogen and ammonia projects.

3. Incorporate qualitative insights from expert interviews and secondary sources to contextualize financial findings and support profitability driven recommendations.

2.3.2 Data Collection
Primary Data
- Expert interview with a hydrogen expert, Mr. Kees Scholler, who provided detailed insights on technical, financial, and operational aspects of hydrogen and ammonia production.

Secondary Data
- Industry reports, academic publications, and government documents on hydrogen and ammonia production technologies.
- Case studies from international projects, such as the Port of Rotterdam’s hydrogen hub and the H2 Future project in Austria.
- Cost data from databases such as IEA, IRENA, and Bloomberg NEF.

2.4 Analytical Frameworks
1. Cost Estimation Model: A detailed cost breakdown based on equipment, infrastructure, labour, and operational expenses.
2. Comparative Benchmarking: A structured comparison of Brazilian cost estimates with international benchmarks.
3. Sensitivity Analysis: An assessment of how changes in key variables (e.g., renewable energy costs, electrolyser prices) impact overall investment requirements.

2.5 Geographic and Temporal Scope

The study focuses on Brazil, emphasizing regions with high renewable energy potential (Northeast Brazil for wind and solar). The analysis covers a 20 year horizon (2025 - 2045) to capture near term investment trends and long-term market developments.

THEORETICAL FRAMEWORK
3.1 Overview of Capital Investment in Hydrogen and Ammonia Facilities

According to *Hydrogen Insight (2025),* Capital investment is essential for developing hydrogen and ammonia production facilities, especially in emerging markets like Brazil. These projects are highly capital-intensive, requiring substantial initial funding for infrastructure, equipment, and compliance. This theoretical framework explores the key components of such investments, emphasizing how financial theories like the Time Value of Money (TVM) and Cost Benefit Analysis (CBA) are applied to evaluate their feasibility. Additionally, it examines how international benchmarking can help identify opportunities to optimize costs and improve strategic decision-making.

3.2 Theories and Concepts in Capital Investment
3.2.1 Time Value of Money (TVM)

The Time Value of Money (TVM) is a fundamental concept in finance that asserts a dollar today is worth more than a dollar in the future due to its earning potential. This principle is particularly relevant to large scale investments, where significant upfront costs are incurred, and returns are spread over several years. In the context of hydrogen and ammonia facilities, TVM is applied to calculate the present value of future cash inflows from sales. By discounting these revenues over the lifecycle of the facility, it is possible to determine the Net Present Value (NPV), which measures the financial viability of the project. This approach is critical for ensuring that the investment aligns with long-term profitability goals *Fan Zhao (2023).*

3.2.2 Cost-Benefit Analysis (CBA)

Cost Benefit Analysis (CBA) is a decision-making tool used to compare the costs of an investment against its expected benefits. For hydrogen and ammonia facilities, CBA involves quantifying expenses like electrolysers, storage infrastructure, land acquisition, and labour, alongside the potential revenue streams from product sales. It also accounts for non-monetary benefits, such as environmental contributions or subsidies. CBA helps determine whether the financial and societal benefits of the project outweigh its capital expenses, supporting informed decisions about resource allocation and investment priorities *Deloitte (2022)*.

3.2.3 Economies of Scale in Capital Investment

Economies of scale play a crucial role in reducing the average cost per unit of output as production scales increase *Hydrogen Insight (2025)*. This is achieved through the efficient allocation of fixed costs and operational efficiencies. For hydrogen and ammonia production, scaling up operations can lead to cost reductions in purchasing electrolysers, infrastructure setup, and energy utilization. Understanding these dynamics helps identify the optimal production capacity for achieving cost efficiency, which is particularly important for Brazil to remain competitive in the global market.

3.2.4 Benchmarking in Capital Investment

Benchmarking involves comparing a project's investment costs and efficiencies against similar international initiatives. This process is invaluable for identifying best practices and cost-saving opportunities *Port of Rotterdam (2023).* For instance, projects like the Port of Rotterdam hydrogen hub and Australia's Hydrogen Energy Supply Chain provide insights into cost structures and operational efficiencies. Applying these benchmarks to Brazil's unique context considering factors like renewable energy availability and labour costs can enhance strategic planning and cost optimization.

3.2.5 Sensitivity Analysis for Investment Risk

Sensitivity analysis is a technique used to evaluate how changes in key variables affect the overall outcomes of a project. In the case of hydrogen and ammonia facilities, it examines the impact of fluctuations in costs, such as electrolysers or renewable energy prices, on the project's financial feasibility. This analysis allows stakeholders to anticipate potential risks and uncertainties in the market, ensuring robust risk management strategies are in place. By modelling different scenarios, sensitivity analysis aids in mitigating risks related to technological advancements or economic changes *D Bellotti (2022).*

3.3 Key Components of Capital Investment in Hydrogen and Ammonia Facilities

Capital investment in hydrogen and ammonia production facilities comprises several key components. Equipment costs, such as electrolysers, hydrogen storage tanks, and ammonia synthesis units, represent a significant portion of the investment. Additionally, infrastructure expenses, including land acquisition and facility construction, are critical for project setup *Queensland Nitrates Pty Ltd. (2020).* Regulatory and compliance costs, such as meeting Brazil's environmental standards and obtaining necessary permits, also add to the financial burden. Lastly, workforce development investments, including skilled labour training and operational maintenance, are essential for ensuring long-term project sustainability.

3.4 Capital Investment Models for Analysis

3.4.1 Levelized Cost of Hydrogen (LCOH)

The Levelized Cost of Hydrogen (LCOH) is a critical financial metric used to evaluate the economic viability of hydrogen production technologies over the lifespan of a project. Similar to the Levelized Cost of Electricity (LCOE) in the power sector, LCOH represents the average cost per kilogram of hydrogen produced, accounting for all capital expenditures

(CAPEX), operational expenditures (OPEX), financing costs, and the total volume of hydrogen generated over time *International Renewable Energy Agency (2020)*. LCOH provides a standardized basis for comparing different hydrogen production methods (green, blue, or grey hydrogen) and assessing the competitiveness of hydrogen projects across various regions and technologies. It is particularly important in investment decision-making, as it incorporates both technical and economic performance indicators to reflect the true cost of production.

3.4.2 Net Present Value (NPV) Model

The NPV model is a widely used tool in financial analysis for evaluating the profitability of investments. It calculates the difference between the present value of cash inflows and the initial capital costs. For hydrogen and ammonia facilities, NPV identifies break-even points and profitability thresholds, providing a clear measure of long-term viability *Elisa Cursio (2025).*

3.4.2 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) measures the expected return on an investment by calculating the discount rate at which the NPV equals zero. This metric helps compare the project's returns with the company's required rate of return, ensuring that the investment meets profitability standards *Investopedia (2025).*

3.4.3 Payback Period

The payback period is a straightforward measure that calculates the time required to recover the initial investment from project revenues. This metric is particularly useful for quick assessments and for stakeholders seeking to minimize financial risks in capital-intensive projects.

3.5 Application to the Research

The theoretical models discussed above will be applied to estimate the profitability of hydrogen and ammonia production facilities in Brazil. By analysing key cost components such as equipment, labour, and infrastructure, the study will provide a comprehensive understanding of potential revenue streams and return on investment. Benchmarking against international projects will further enhance this analysis by identifying operational efficiencies and profit-maximizing strategies. Finally, sensitivity analysis will be conducted to simulate various market conditions and price fluctuations, offering actionable recommendations to improve profitability and ensure long-term financial viability. This theoretical framework highlights profitability as a cornerstone of financial feasibility for hydrogen and ammonia production in Brazil. By leveraging concepts such as the Time Value of Money (TVM), Levelized Cost of Hydrogen (LCOH), Cost-Benefit Analysis (CBA), economies of scale, benchmarking, and sensitivity analysis, it provides a structured approach to evaluating revenue potential, cost structures, and financial risks. These insights will form the basis for optimizing financial strategies and ensuring Brazil's long-term competitiveness in the global hydrogen economy.

DATA RESEARCH

4.1 Overview

This chapter presents the data research methodology used to estimate capital investment for a hydrogen and ammonia production facility in Brazil. The study employs a mixed-methods approach that combines quantitative and qualitative data. It focuses on four pillars: cost estimation modelling, benchmarking analysis, sensitivity testing, and theoretical capital investment frameworks such as TVM, LCOH, and CBA.

4.2 Capital Investment Cost Structure

Component Description Source Electrolyser system Equipment to split water into hydrogen and oxygen using renewable electricity. Hydrogen compression and storage Infrastructure to store hydrogen in pressurized tanks or cryogenic vessels.

4.3 Secondary Data Sources

Secondary data was obtained from global organizations and industry reports to ensure a comprehensive understanding of current hydrogen and ammonia infrastructure trends. These sources include:

1. IRENA (2022): Provided global electrolyser CAPEX benchmarks and cost reduction trajectories.
2. IEA (2023): Offered guidance on ammonia production systems, hydrogen storage techniques, and infrastructure investments.
3. Bloomberg NEF (2023): Contributed data on Levelized Cost of Hydrogen (LCOH) forecasts and policy incentives in key markets.
4. McKinsey & Company (2023): Outlined strategic investment recommendations and risk factors for hydrogen production.
5. Hydrogen Council (2023): Supplied global hydrogen demand projections and infrastructure scaling metrics. International case studies, such as H2Future (Austria), HyNet (UK), and Port of Rotterdam (Netherlands), were also analysed to provide benchmark data and cost structures (Hydrogen Europe, 2023; Deloitte, 2023).

ANALYSIS AND CONCLUSION

5.1 Overview

This chapter presents a synthesis of the research findings, integrating quantitative results with qualitative insights to assess the overall profitability and viability of establishing a hydrogen and ammonia production facility in Brazil. Drawing from detailed capital cost modelling, benchmarking against international projects, sensitivity testing, and expert input, this analysis evaluates whether such a project aligns with investment expectations in the emerging global hydrogen economy.

5.2 Profitability of Hydrogen Production and Storage in Brazil: Financial Performance and Global Benchmarking

This subchapter evaluates the estimated profitability of constructing a hydrogen production and storage facility in Brazil by examining capital investment requirements, operating costs, and projected revenue. Additionally, it benchmarks Brazil's performance against global hydrogen projects to assess its relative competitiveness.

5.2.1 Capital Investment and Operating Costs

The total capital investment (CAPEX) for the project amounts to $182.25 million, covering:

- Electrolyser system: $60.00 million
- Ammonia synthesis unit: $75.00 million
- Supporting infrastructure (water, compression, storage): $47.25 million

The annual operating expenditure (OPEX) is estimated at $24.22 million, which includes:

- Electricity: $15.75 million (based on a renewable PPA price of $30/MWh for 525 GWh/year)
- Maintenance: $5.47 million (3% of CAPEX)
- Other operational costs: $3.00 million (personnel, utilities)

5.2.2 Revenue Potential

The project generates two revenue streams:

- Hydrogen: 10,000,000 kg/year sold at $3.00/kg
- Ammonia: 60,000 tons/year sold at $600/ton = $30.0 million/year = $36.0 million/year.

This results in a total annual revenue of $66.0 million, and a net annual cash flow of $41.78 million after deducting OPEX.

5.2.3 Financial Performance Metrics

Key indicators derived from a 20 year financial model using an 8% discount rate include:

1. Net Present Value (NPV), The discounted cash flow over 20 years is $410.24 million, leading to an NPV of $228.00 million after subtracting CAPEX. This strong positive NPV confirms that the project creates significant financial value.
2. Internal Rate of Return (IRR), Calculated at 23%, the IRR significantly exceeds the 8% discount rate, indicating a high return on investment and making the project highly attractive to investors.
3. Payback Period, The project's payback period is approximately 4.36 years (4 years and 4 months), meaning the initial capital is recovered early within the project's operational life, reducing long-term financial risk.
4. Levelized Cost of Hydrogen (LCOH), The discounted LCOH is $2.10/kg, making it competitive with global producers. For comparison:
   - Germany: $1.44–3.11/kg (IRENA, 2020)
   - Indonesia: $5–10/kg (IRENA, 2020)
   - United Arab Emirates: $1.86–2.75/kg (World Bank, 2023)

This places Brazil favourably in the mid to lower cost range, largely due to its access to affordable renewable energy and favourable site conditions.

5.2.4 Profitability in a Global Context

When benchmarked against similar international projects, Brazil's hydrogen and ammonia facility demonstrates strong relative profitability. Its combination of:

- Competitive CAPEX;
- Low cost renewable electricity;
- Scalable production design Positions it as an attractive investment in the emerging global hydrogen economy.

The benefit cost ratio (BCR) of 1.98 further underscores this, showing that for every $1 invested, nearly $2 in value is generated over the life of the project. In conclusion, Brazil's hydrogen and ammonia production potential is not only financially viable but also strategically competitive. It offers returns that compare favourably with international benchmarks and aligns with long-term sustainability and energy transition goals.

5.3 Main Cost Components in Hydrogen and Ammonia Production Facilities

The integration of hydrogen production with ammonia synthesis involves a complex and capital intensive infrastructure. This subchapter outlines the main cost components involved in both the construction (CAPEX) and operation (OPEX) of such facilities, based on empirical data and industry benchmarks from the case study in Brazil.

Category Component Description Cost / Value Source: Capital Expenditure (CAPEX) Electrolyser System Green hydrogen production (60 MW capacity, powered by renewables) $60.0 million. Ammonia Synthesis Unit Haber-Bosch process reactors and compressors $75.0 million. Operational Expenditure (OPEX) Supporting Infrastructure Civil Works & Site Development EPC Management Regulatory Compliance & Permits Total CAPEX Electricity Maintenance Other Operating Costs Total OPEX Water supply, hydrogen compression, storage, electrical systems Land, roads, foundations, construction Engineering, procurement, and construction oversight Licensing, environmental, and safety regulations Combined capital expenditure for full facility setup Annual power cost for electrolysis (525 GWh/year & $30/MWh) Regular servicing & component replacement (3% of CAPEX) Labor, utilities, consumables, admin. Total annual operating expenses $47.25 million (Included in above total)

(Included) (Included) $182.25 million $15.75 million / Year $5.47 million / year $3.00 million / year $24.22 million /year

5.4 Influence of Geographic, Economic, and Technological Factors on the Profitability of Hydrogen Production in Brazil

The profitability of hydrogen production projects is shaped by a combination of geographic advantages**,** economic conditions, and technological maturity. Brazil presents a unique case, offering favourable renewable energy resources, emerging infrastructure, and cost dynamics that make it a strong candidate for green hydrogen and ammonia development. This subchapter analyses how each of these factors impacts the financial performance and investment attractiveness of such projects in the Brazilian context.

5.4.1 Geographic Factors

5.4.1.1 Abundant Renewable Resources

Brazil’s Northeast region is rich in solar and wind energy, enabling the supply of low cost, clean electricity required for water electrolysis. According to the report, Power Purchase Agreement (PPA) for renewable electricity is estimated at $30/MWh**,** one of the lowest globally. This leads to a competitive Levelized Cost of Hydrogen (LCOH) of $2.10/kg**,** enhancing Brazil's cost leadership in hydrogen production.

5.4.1.2 Strategic Location

Brazil’s proximity to export markets in Europe and North America and access to ports supports international trade of hydrogen and green ammonia. Efficient transport logistics enhance market access and reduce export costs.

5.4.2 Economic Factors

5.4.2.1 Competitive Operational Costs

Brazil benefits from relatively low labour and land costs, which contribute to a more affordable cost structure compared to many OECD countries. The report highlights:

- Annual operating costs are estimated at $24.22 million, significantly improving project margins.
- Positive Net Present Value (NPV) of $228 million and IRR of 23% over a 20 year horizon make the project financially attractive.

5.4.2.2 Policy and Incentive Landscape

While still evolving, Brazil’s regulatory environment shows promise, with growing interest in hydrogen policy support. The case study includes:

- 10% of total project financing from government subsidies/grants, reducing capital burden.
- Potential future carbon credits and international climate finance may improve returns.

5.4.3 Technological Factors

5.4.3.1 Electrolyser and Process Integration

The project uses 60 MW electrolysis capacity, paired with an ammonia synthesis unit to produce 60,000 tons of ammonia per year. This integration allows:

- Efficient use of hydrogen and nitrogen resources.
- Additional revenue from ammonia markets, improving financial performance.

5.4.3.2 Cost Reduction Through Technology Maturity

- International benchmarks and economies of scale are expected to drive further CAPEX reductions, particularly in electrolysers.

- Brazil's facility design anticipates future technological upgrades, which could lower the LCOH below $2.00/kg in the long term.

5.5 Conclusion

This research investigated the strategic and financial viability of establishing a green hydrogen and ammonia production facility in Brazil. Through detailed cost modelling, expert validation, and international benchmarking, the study confirmed Brazil’s strong potential in becoming a key player in the global hydrogen economy. The analysis shows that Brazil benefits from a unique combination of low-cost renewable energy, favourable geography, and a scalable production model. The modelled project demonstrates a Net Present Value (NPV) of $228 million, an Internal Rate of Return (IRR) of 23%**,** and a payback period of 4.36 years, indicating strong financial attractiveness. The Levelized Cost of Hydrogen (LCOH) of $2.10/kg places Brazil among the most competitive countries globally, supported by long-term renewable PPAs at $30/MWh. However, realizing Brazil's full hydrogen potential requires strategic alignment across multiple areas. Despite its advantages, the market still faces risks related to infrastructure development, skilled labour shortages, safety concerns, and regulatory uncertainty.

5.6 Recommendations and Policy Implications

To ensure the economic viability and scalability of hydrogen and ammonia production in Brazil, a coherent policy framework and strategic public private coordination are required. This section presents actionable recommendations rooted in the financial modelling and market analysis conducted in this research, with a specific focus on developing a robust national hydrogen economy.

5.6.1 Develop a National Hydrogen Strategy

Currently, Brazil lacks a consolidated and enforceable national hydrogen strategy, which creates significant uncertainty for investors and hinders coordinated infrastructure planning. As detailed in Section 4.6.1 of the report, this regulatory gap could delay project approvals and increase perceived risk among financial institutions. A dedicated strategy should define medium and long term production targets such as achieving 10 GW of installed electrolyser capacity by 2035 as well as identify priority regions for deployment. The Brazilian Northeast, highlighted in Section 4.3 of the report, offers exceptional solar and wind resources and access to export infrastructure, making it an ideal location for hydrogen hubs. The strategy should also include timelines for supporting infrastructure, including hydrogen transport pipelines, ammonia storage terminals, and grid enhancements to integrate renewable energy. Furthermore, as emphasized in Section 4.2.3, the lack of skilled labour is a barrier to execution. Therefore, the strategy should include workforce development goals and incentives for vocational training in hydrogen technology and plant operations.

5.6.2 Expand Fiscal Incentives and Green Financing

Hydrogen projects are capital intensive, with total capital expenditure (CAPEX) for the modelled facility estimated at $182.25 million (Section 4.5.2). To mitigate investment risk and enhance bankability, Brazil should expand fiscal incentives. Section 4.5.4 shows that even a modest grant covering 10% of CAPEX significantly improves project viability. Additionally, production-based incentives could offer fixed payments per kilogram of green hydrogen or ton of green ammonia produced, directly improving the internal rate of return (IRR), which in this case is calculated at 23% over 20 years (Section 4.5.8.2). Access to concessional green financing such as low interest loans from BNDES or international institutions like the Green Climate Fund would further reduce financing costs. Section 4.5.5 discusses the impact of electricity pricing on project viability; securing long-term Power Purchase Agreements (PPAs) at or below $30/MWh is critical for maintaining an affordable Levelized Cost of Hydrogen (LCOH), currently estimated at $2.10/kg (Section 4.5.7). Tax exemptions on essential imported equipment (PEM electrolysers, compressors, air separation units) should also be considered, as import duties can significantly inflate CAPEX.

5.6.3 Strengthen Regulatory Frameworks

The absence of hydrogen specific regulation remains a structural barrier, as discussed in before. To resolve this, Brazil should implement a national regulatory framework addressing hydrogen production, transportation, storage, and safety. This includes developing technical standards aligned with global certification systems such as CertifHy and the EU's Renewable Energy Directive (RED II), to ensure Brazilian hydrogen meets international quality benchmarks for export. The report highlights the need for certification systems to unlock revenue from foreign markets and carbon credit schemes. In addition, Brazil must streamline environmental licensing and clarify institutional responsibilities among ANEEL, ANP, IBAMA, and other agencies involved in infrastructure oversight. Delays in licensing currently averaging 12 to 18 months were flagged as a significant project risk. Grid connection rules must also be updated to facilitate the integration of high capacity renewable energy sources into hydrogen production systems, reducing curtailment and improving operational reliability. Lastly, a national carbon accounting framework should recognize emissions avoided through green hydrogen production, enabling producers to monetize carbon abatement through domestic or international credit markets. Finally, international engagement should be intensified. As Brazil aspires to become a global supplier of green hydrogen and ammonia, strategic partnerships with hydrogen-importing countries such as Germany, Japan, and the Netherlands are essential. These partnerships can promote technology transfer, joint investment in port infrastructure, and secure long term offtake agreements. Participation in global hydrogen governance platforms like the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and the IRENA Hydrogen Partnership would enhance Brazil's credibility and alignment with emerging global standards.

By implementing these recommendations, Brazil can build a competitive and sustainable hydrogen economy. The enabling environment described here would unlock the full potential of the profitable project modelled in this research, which already shows strong indicators such as a payback period of 4.36 years and a benefit cost ratio of 1.98. These figures reinforce the urgency and importance of supportive policy action in catalysing private investment and international partnerships for Brazil's hydrogen future.

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