CASE STUDY

BUSINESS MODELS FOR GREEN HYDROGEN IN LATIN AMERICA

4. KAHIROS GREEN HYDROGEN TRANSPORTATION PROJECT IN URUGUAY

This publication is part of the activities of the project “Advancing a Regional Approach to the Green Hydrogen Economy in Latin America and the Caribbean” (H2 ¡Vamos! / H2 Go!), an initiative led by the United Nations Environment Programme (UNEP) and funded by the Green Climate Fund. The project aims to strengthen regional capacities to promote a just, inclusive, and sustainable green hydrogen economy.

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1. EXECUTIVE SUMMARY

The Kahirós Project, located in Fray Bentos, Uruguay, is the first initiative in Latin America dedicated to the production and use of green hydrogen for heavy-duty freight transportation. Led by a consortium of companies and financed by Grupo Santander [1], the project aims to replace diesel trucks with hydrogen-powered vehicles, reducing CO_2 emissions and promoting the decarbonization of the logistics sector.

The plant will feature a 4.9 MW solar park and a 2 MW electrolyzer [2], enabling the production of 77 tons of green hydrogen per year. The initiative includes the operation of six hydrogen-powered heavy-duty trucks, each with a range of 700 km per refill and refueling times of less than 30 minutes.

With an initial investment of USD 38.6 million [3], the project is set to begin operations in 2026 and expects to reduce up to 870 tons of CO_2 annually [4], positioning Uruguay as a leader in sustainable transportation.

2. BACKGROUND AND CONTEXT

The transport sector in Uruguay accounts for a significant share of greenhouse gas emissions, primarily due to the intensive use of fossil fuels in heavy logistics. However, the country stands out for its predominantly renewable electricity matrix. Between 2016 and 2023, an average of 94% of electricity generation came from renewable sources [5], thanks to the integration of hydro, wind, solar, and biomass energy. This creates an ideal environment for the development of green hydrogen projects by ensuring a clean and stable electricity supply.

The Kahirós Project emerges within this context as a pilot initiative to decarbonize freight transport in the forestry industry, leveraging the country's solar potential and sustainable energy infrastructure. Its strategic location in Fray Bentos allows efficient integration of hydrogen production with existing logistics operations.

3. PROJECT DESCRIPTION

The Kahirós Project, based in Fray Bentos, Uruguay, is a pioneering initiative in Latin America focused on producing and using green hydrogen to decarbonize heavy freight transport in the forestry sector. The project integrates renewable energy, hydrogen production, and a fleet of hydrogen-powered electric trucks.

Hydrogen will be produced using a 4.9 MW photovoltaic solar park that powers a 2 MW PEM electrolyzer, with the capacity to generate 77 tons of green hydrogen annually. The hydrogen will be stored in high-pressure tanks and distributed through a dedicated hydrogen refueling station (hydrolinera), designed to allow rapid refueling in less than 30 minutes [2].

The fleet will consist of six heavy-duty trucks, each with a 700-kilometer range per refill and a 48-ton payload capacity. These vehicles will be operated by FrayLog, which provides logistics services for Montes del Plata, transporting timber on high-demand routes. The use of these trucks is expected to avoid approximately 870 tons of CO_2 emissions per year [2], in addition to reducing local pollution by eliminating NO_x and fine particulate emissions.

The project also includes technical training programs for personnel to facilitate the transition to hydrogen technologies. Additionally, real-time monitoring systems will be implemented to optimize operations and assess environmental and logistical performance.

4. USE OF TECHNOLOGY

The Kahirós Project in Uruguay uses advanced technology for the production, storage, distribution, and use of green hydrogen in heavy-duty freight transport. The technological process is described in detail below:

1. Green Hydrogen Production

Green hydrogen is produced through a 2 MW proton exchange membrane (PEM) electrolyzer, powered by a 4.9 MW photovoltaic solar park. The electrolysis process splits water into hydrogen and oxygen, ensuring carbon-free production [2].

- **Energy Source:** Solar panels supply renewable electricity to the electrolyzer.
- **Electrolysis:** Purified water is split into hydrogen and oxygen using an electric current.
- **Total Production:** 77 tons of green hydrogen per year.

2. Storage and Distribution

The hydrogen produced is compressed and stored in high-pressure tanks designed to ensure stability and safety. It is then transported to a specialized hydrogen refueling station (hydrolinera), where the trucks are refueled [2].

- **Storage:** High-pressure tanks are used to prevent leaks and maximize storage efficiency.
- **Refueling Station:** Enables fast hydrogen refills in less than 30 minutes.

3. Refueling and Energy Conversion

The hydrogen trucks are designed to be refueled at the project's hydrogen station, where hydrogen is transferred to their internal storage tanks. Then, the hydrogen is converted into electricity via a fuel cell [2].

- **Refueling Process:** The truck connects to the station, and hydrogen is transferred from the storage tanks to the vehicle.
- **Energy Conversion:** In the fuel cell, hydrogen reacts with oxygen from the air, generating electricity and releasing water as the only by-product.

4. Truck Operation

The hydrogen-powered electric trucks will be operated by FrayLog, which provides logistics services to Montes del Plata for timber transportation. Each unit has a 700 km range per refill and a load capacity of 48 tons.

- **Electric Motor:** Powered by the electricity generated in the fuel cell.
- **Energy Optimization:** According to the manufacturer's specifications, the trucks are equipped with a battery system that stores additional energy to provide extra power during key moments, such as acceleration or steep inclines [6].

- **Emission Reduction:** The use of hydrogen enables the elimination of approximately 870 tons of CO_2 per year, as well as local pollutants such as NOx and fine particles.

These vehicles operate under high pressure, allowing for ranges exceeding 700 bar and the transport of loads up to 48 tons [2].

5. VALUE PROPOSITION

The Kahirós Project offers an innovative solution to decarbonize heavy-duty freight transport in Uruguay's forestry industry. Its value proposition combines renewable energy, green hydrogen production, and a fleet of fuel cell trucks, significantly reducing the sector's environmental impact.

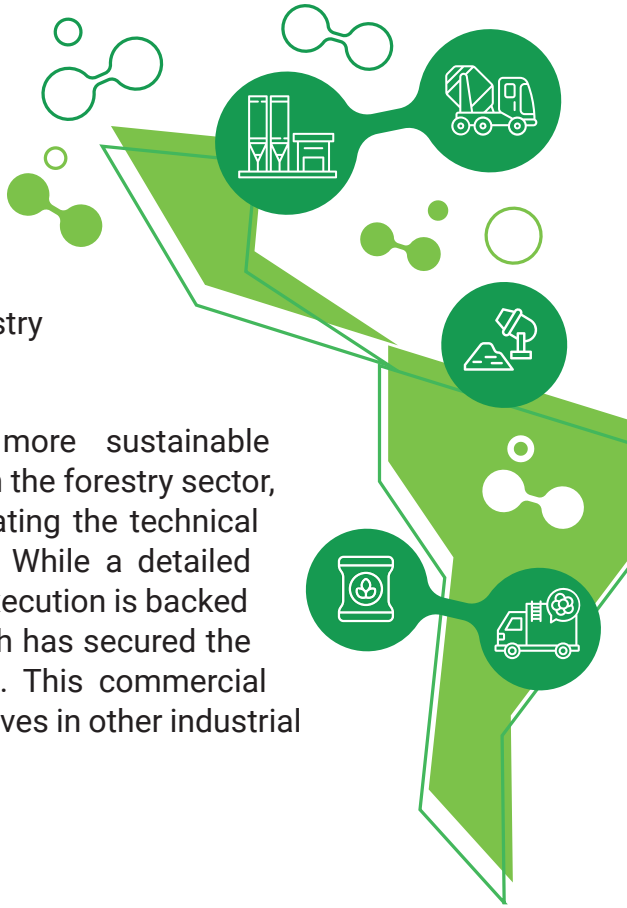
One of its main benefits is the reduction of 870 tons of CO_2 emissions per year [4], in addition to eliminating local pollutants such as NOx and fine particulate matter. With a range of 700 km and refueling times under 30 minutes, the trucks deliver competitive performance compared to diesel models, without compromising operational efficiency [2].

The project also promotes technical training in hydrogen and sustainable mobility, laying the groundwork for the expansion of this technology in Uruguay. Moreover, Kahirós positions itself as a replicable model across Latin America, demonstrating the feasibility of green hydrogen in heavy freight transport and encouraging its adoption in other industrial sectors.

6. SIMILAR PROJECTS IN LATIN AMERICA AND REGIONAL ADAPTATION

The Kahirós Project is part of a series of initiatives across Latin America aiming to accelerate the adoption of green hydrogen in heavy transport and industrial sectors. Several countries have identified hydrogen as a key alternative to reduce emissions and enhance energy competitiveness in strategic areas.

In Costa Rica, the company Cavendish is leading the development of hydrogen-powered trucks and buses within the framework of the national decarbonization strategy. The country has already successfully tested hydrogen in passenger transport and is now looking to expand its use into heavy freight logistics [7].



Brazil, in turn, is advancing with the Green Hydrogen Hub at the Port of Pecém, a large-scale project aiming to position the country as a key player in the production, export, and use of hydrogen for transportation and industry [7].

These projects show that the transition toward more sustainable transportation is underway in the region. With its focus on the forestry sector, Kahirós positions itself as a reference model demonstrating the technical feasibility of green hydrogen in heavy freight logistics. While a detailed economic analysis of the project is not yet available, its execution is backed by a long-term commitment from Montes del Plata, which has secured the contracting of hydrogen-powered transport services [2]. This commercial backing may encourage the development of similar initiatives in other industrial sectors and neighboring countries.

7. MARKET SEGMENT

The Kahirós Project is designed to meet the need for decarbonizing heavy freight transport. While this project is focused on a pilot within the forestry industry, similar initiatives could be applied to industrial sectors with high energy consumption. Its target market includes:

- **Forestry Industry**: Companies engaged in the production and export of timber products, such as Montes del Plata, aiming to reduce their carbon footprint and improve the sustainability of their transport logistics [2].
- **Heavy-Duty Freight Transport:** Commercial fleets interested in adopting clean technologies to reduce operating costs and comply with environmental regulations.
- **Governments and Institutions:** Public bodies promoting the energy transition and able to incentivize adoption through infrastructure development policies and funding mechanisms [5].
- **Investors and Strategic Partners:** Companies and investment funds looking to participate in the development of green hydrogen in the region.

The project represents an opportunity to expand the use of green hydrogen into other industrial sectors, including agribusiness and port logistics, where full electrification of transport is not currently viable.

8. KEY ACTIVITIES

The development of the Kahirós Project involves several clearly defined phases, from initial planning to commissioning and operation, ensuring the project's technical and environmental viability. The following phases have been validated using official information available [2][4]:

PHASE 1: PRESENTATION AND INITIAL PLANNING (2024)

- Public presentation of the project, confirmation of strategic partners, and financing.
- Coordination with local and national authorities for approvals and permitting.

PHASE 2: PREPARATIONS AND CONSTRUCTION (2025)

- Start of civil works and site preparation in Fray Bentos.
- Construction of the solar park and necessary infrastructure for green hydrogen production, storage, and distribution.

PHASE 3: START OF OPERATIONS AND VALIDATION (2026)

- Installation and commissioning of the electrolyzer and the hydrogen refueling station (hydrolinera).
- Start of green hydrogen production and initial operation of the truck fleet.
- Initial monitoring of operational, technical, and environmental performance to ensure system effectiveness.

These phases, validated through official sources, outline the roadmap of the Kahirós Project, positioning it as a regional benchmark for sustainable mobility powered by green hydrogen.

9. KEY PARTNERS

The success of the Kahirós Project relies on the strategic collaboration of various companies and institutions, each playing a critical role in the project's implementation, operation, and scalability:

- **NASPUY S.A.:** The legal entity managing the project, formed by Ventus, Fraylog, and Hyundai Fidocar—directly responsible for the comprehensive development of the Kahirós Project [2][4].
- **Ventus:** A company specialized in structuring, developing, and building renewable energy projects in Uruguay. It is responsible for the technical implementation and overall coordination of the project [2].
- **Fraylog S.A.:** A logistics and forestry transport group, and one of the main logistics operators for Montes del Plata and UPM. Fraylog will directly operate the hydrogen-powered truck fleet [2].
- **Hyundai Fidocar:** Official representative of Hyundai in Uruguay, providing automotive and sustainable mobility solutions. It will supply the Hyundai Xcient trucks equipped with fuel cell technology for the project [2][6].
- **Montes del Plata:** A forestry sector company that strategically supports the project, securing sustained demand over ten years for zero-emission transport services [2].
- **Grupo Santander:** A key financial institution, providing the financing that ensures the execution and economic viability of the project [1].

The coordinated collaboration between these strategic partners strengthens the successful implementation of the Kahirós Project, establishing it as a replicable model for Uruguay and Latin America.

10. RESULTS AND BENEFITS

The Kahirós Project will generate positive environmental, economic, and social impacts, positioning itself as a model for the decarbonization of heavy freight transport in Uruguay.

1. Environmental Benefits

- **Emission reductions:** An estimated 870 tons of CO_2 will be avoided annually with the initial hydrogen truck fleet, eliminating reliance on diesel [4].
- **Reduction of local pollutants:** The shift to green hydrogen will eliminate NOx and fine particulate emissions, improving air quality [4].
- **Efficient renewable energy use:** Hydrogen will be produced using solar energy, ensuring environmental sustainability [2].

2. Economic Impact

- **Future cost reduction:** According to the International Energy Agency (IEA), green hydrogen costs are expected to drop significantly in the medium term due to economies of scale, making the technology competitive with diesel [10].
- **Attraction of investment:** The project may attract international investment in infrastructure and sustainable mobility.
- **Strengthening the forestry sector:** Companies such as Montes del Plata will benefit by improving their competitiveness and environmental performance [2].

3. Social Impact

- **Job creation:** More than 70 new jobs will be generated in hydrogen production, maintenance, and infrastructure [4].
- **Specialized training:** Technical training in clean technologies will support the energy transition [2].

These benefits position the Kahirós Project as a key reference for the transition toward a sustainable economy in Uruguay and Latin America.

11. COST STRUCTURE

The cost structure of the Kahirós Project is divided into initial investment and recurring operational costs, reflecting the necessary expenditures for infrastructure, production, storage, and distribution of green hydrogen [4].

1. Initial Investment:

- Construction of the photovoltaic solar park.
- Implementation of the 2 MW PEM electrolyzer.
- Infrastructure for hydrogen storage and distribution (refueling station).
- Initial acquisition of six hydrogen-powered heavy-duty trucks.
- Installation of control, monitoring, and safety systems.
- Technical training of personnel for operation and maintenance.

2. Annual Operating Costs:

- Continuous production of green hydrogen (energy and water supply).
- Preventive and corrective maintenance of the installed infrastructure.
- Operation of the truck fleet (refueling and maintenance).
- Environmental monitoring and periodic audits.
- Ongoing training and technical updates for operating personnel.

Note: This structure presents the main components without specifying exact amounts due to the absence of verifiable figures in the available documentation.

12. FINANCING STRUCTURE

The Kahirós Project has a solid financing structure, combining private investment and bank financing to ensure its economic viability and successful implementation [1][2].

- **Total Investment: The total investment in the project is estimated at USD 38,600,000 [4].**

FUNDING SOURCES:

1. Private Investment:

- **Grupo Santander:** Acts as the project's primary investor, providing a significant portion of the capital required for development [1].

2. Partner Companies:

- **Ventus:** A renewable energy company contributing its expertise in structuring and building the plant [2].
- **Fraylog S.A.:** A logistics and transport company responsible for operating the hydrogen-powered truck fleet [2].
- **Hyundai Fidocar:** Hyundai's official representative in Uruguay, supplying hydrogen trucks and offering sustainable mobility solutions [2][6].

3. Main Client:

- **Montes del Plata:** A forestry company that will utilize the transport service provided by Fraylog, securing demand for the hydrogen produced and supporting the project's economic viability [2].

This combination of private investment and bank financing provides a strong financial foundation for the implementation and successful operation of the Kahirós Project, positioning it as a benchmark for decarbonizing heavy-duty transport in Uruguay.

13. REVENUE SOURCES

The Kahirós Project has been designed with a business model primarily based on the provision of sustainable logistics services using hydrogen-powered trucks. The main revenue streams include:

- **Zero-Emission Transport Services:** The primary source of income will come from logistics service contracts with Montes del Plata and potentially other industrial companies. These companies will pay a premium compared to traditional services, valuing the benefit of significant carbon emission reductions [2].
- **Carbon Credits:** The annual reduction of approximately 870 tons of CO_2 will allow the generation and sale of carbon credits in international markets, with additional estimated revenue ranging from USD 17,000 to 26,000 per year [4].
- **Government Incentives:** The project benefits from economic incentives offered by the Uruguayan government that promote the use of renewable energy and sustainable mobility [11]. (For more information see: https://www.gub.uy/ministerio-industria-energia-mineria/politicas-y-gestion/aspectos-interes-instrumentos-promocion)

Combined, these revenue sources will ensure a stable and sustainable cash flow for the initial operation, with growth potential as the scale of operations increases.

14. LESSONS LEARNED

The development of the Kahirós Project provides key insights for future initiatives related to green hydrogen and sustainable mobility in Latin America, especially in the heavy transport sector.

1. Importance of Early Financing

Securing financing in advance—such as the support obtained from Grupo Santander—has proven essential for reducing risks, accelerating implementation, and demonstrating that banks are willing to back innovative clean energy projects [1].

2. Competitive Advantages of Hydrogen Fuel Cell Vehicles (FCEVs) Over Battery Electric Vehicles (BEVs):

The specific operational advantages of hydrogen-powered trucks—such as longer range, faster and more efficient refueling times, and the ability to carry heavy loads without significant performance loss—make this technology highly competitive compared to fully electric alternatives [6][10].

3. Infrastructure and Logistics Challenges:

Planning experience shows that developing specialized hydrogen infrastructure—such as refueling stations (hydrolineras) and safe storage systems—requires special attention from the early stages due to its technical and logistical complexity [4].

4. Guaranteed Demand (Offtaker):

The economic viability of the project hinges on securing long-term demand (offtaker) from the outset, which justifies the initial investments in infrastructure and vehicles. In this case, Montes del Plata plays a key role by committing to sustained use of the logistics service, making the project viable from inception [2].

5. Regulatory Framework and Government Support:

The successful development of green hydrogen projects greatly depends on clear regulations and appropriate government incentives. This support is fundamental to fostering the adoption of sustainable technologies in heavy-duty transport [11].

15. CONCLUSIONS

This project represents a significant step forward in the decarbonization of freight transport in Latin America through the production and use of green hydrogen. By integrating renewable energy, advanced electrolysis technology, and a fleet of zero-emission trucks, Kahirós establishes an innovative and replicable model [2][4].

- **Positive Environmental Impact:** An estimated reduction of 870 tons of CO_2 per year, in addition to the elimination of local emissions of NOx and fine particulate matter [4].
- **Financial Strength:** With a total investment of USD 38,600,000, the project has secured key financing, particularly with the support of Grupo Santander [1].
- **Technological Innovation:** Deployment of cutting-edge technologies, including a high-efficiency hydrogen refueling station to ensure continuous fuel supply for the hydrogen truck fleet [6].
- **Sustainable Business Model:** The project is based on providing sustainable transport services, supported by long-term contracts with companies such as Montes del Plata [2].
- **Scalability and Regional Relevance:** This model can be replicated in other industrial sectors and countries across Latin America, serving as a reference for future green hydrogen initiatives in transportation.

> ***Kahirós highlights the crucial role of hydrogen in the energy transition and sets a precedent for upcoming projects in the region. With a focus on sustainability, operational efficiency, and structured financing, the project positions Uruguay as a benchmark in clean freight mobility in Latin America***

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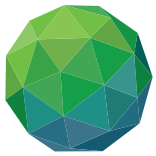

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