Hydro-E Blocks, a Book & Claim Blockchain & AI-powered Solution in the Hydrogen Industry

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1. Introduction

To gain a comprehensive understanding of Hydro-E Blocks project, we must first define the concepts of Hydrogen and Blockchain, then look into their intersection and the potential of such a solution within this specific use case.

Hydrogen is an energy vector that allows to transfer, in space and time, a quantity of energy. Its use within an energy system allows the realization of closed cycles of energy resources which can be done through the exploitation of renewable resources and the deletion of environmental waste [1], reducing by that the dependence on fossil fuels.

In this energy vector era, hydrogen holds the potential to decarbonize carbon-intensive industries, from steel production to refineries. With massive investments, the hydrogen industry is rapidly evolving; 531 new hydrogen and synthetic fuel projects were established in the first half of 2024 alone. Within this, low-carbon hydrogen—and particularly green hydrogen—emerges as a promising solution. Of the 531 projects mentioned, 411 were based on electrolyzers, collectively amounting to a 500 GW capacity [2].

The extensive low-carbon and green hydrogen supply chain has complex upstream and downstream operations linked to various carbon-intensive industries. This results in the proliferation of vast and complex supply chains from production to the end user [3] (Figure 1). This complexity introduces a need to distinguish between green hydrogen and less sustainable alternatives by proving the origin of the green commodity. Therefore, to respond to this urgent need, ensuring the transparency of the operations and establishing trust between stakeholders are critical factors.

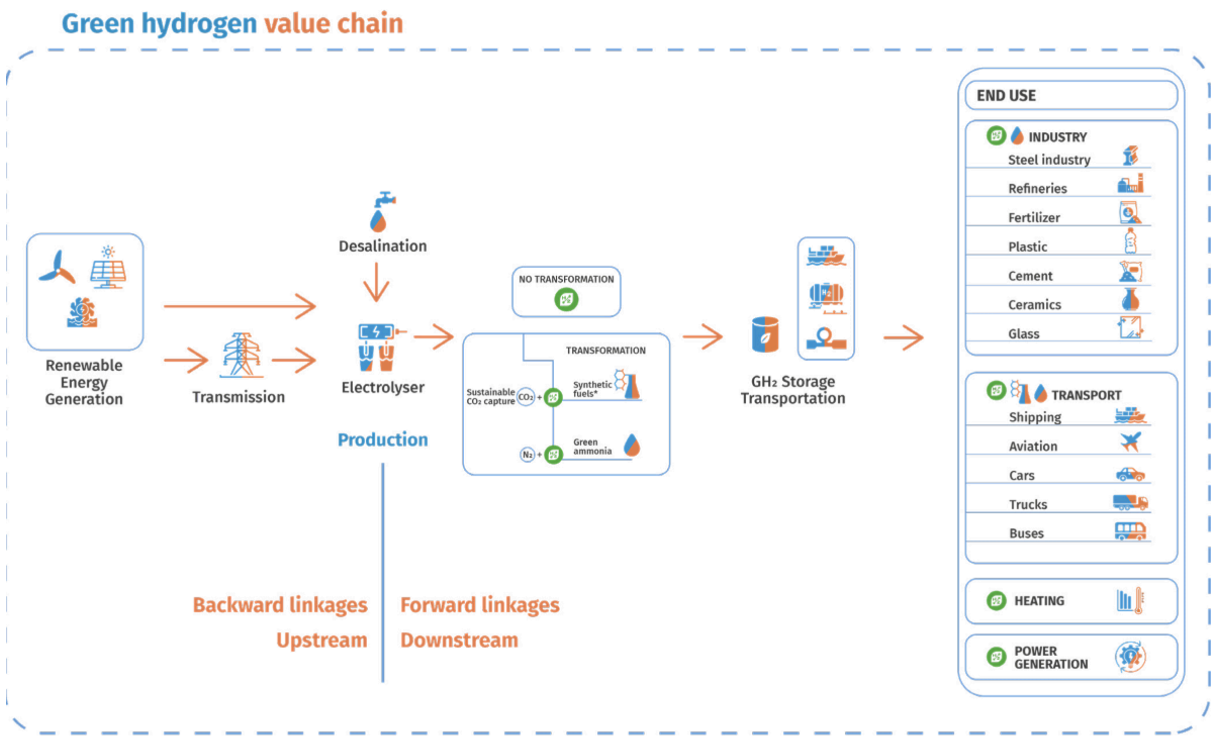


Figure 1: Green Hydrogen Value Chain, IRENA 2024

Blockchain Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. [4] This “simple definition” of Blockchain proposed by “IBM” does not help us grasp the potential of this technology. To fully comprehend what is blockchain, we’ll have to look into the difference between web2 and web3. Web2 is the stage of the internet that we all know with Facebook, Twitter… This stage is known for when users create their own content on these centralized social software platforms. Web3 is a decentralized internet built on blockchains where users control use and access.

Looking into the differences between web2 and web3, we identified 2 key concepts. The first one is the control over transactions, content, and data. The second one is trust. For example, in web2, to complete a transaction of money or information we need to have two to three parties trusting each other; the sending one, the receiving one, and the facilitating one, whereas in web3 the transaction is made whenever the criteria are met and the data is verified [5].

Blockchain has proven its potential in the financial sector, which makes it generally associated with cryptocurrency. However, its true value proposition is its ability to build trust, enhance efficiency, and provide control and security—making it an innovative and optimal solution for various business applications [6]. For example, based on previous use cases in the energy sector, we can identify the benefits of using this technology; its reduced costs, environmental sustainability, and increased transparency for stakeholders while not compromising privacy [7]

Hydrogen and Blockchain Intersection

While we highlighted the need for transparency and trust within the complex hydrogen supply chain, we also showcased blockchain's main value proposition in ensuring these key concepts. By creating a blockchain solution that responds to these challenges, Hydro-E Blocks aims to create a new decentralized verification system for renewable hydrogen. With the transition to web3, we are also enabling new business models that were not possible in web2.

2. The "Why"

The problem is that there is a need to accelerate the adoption of green and low-carbon hydrogen, decrease the reliance on fossil fuels, and ensure a transparent low-cost tracking system to optimize the carbon footprint of different stakeholders in the supply chain.

An Urgent Need For Decarbonization

In this decarbonization mission where we aim to complete a successful energy transition and limit global warming to 1.5°C, hydrogen holds an important role within industries such as refineries, cement, steel, maritime shipping, aviation, etc, [3] its mission translates into the ability of this molecule to decrease reliance on fossil fuels in these different sectors. Using low-carbon and green hydrogen could contribute to more than 20 percent of annual global emissions reductions by 2050 [8], with a 95% reduction in carbon intensity in steelmaking [9] (Figure 2).

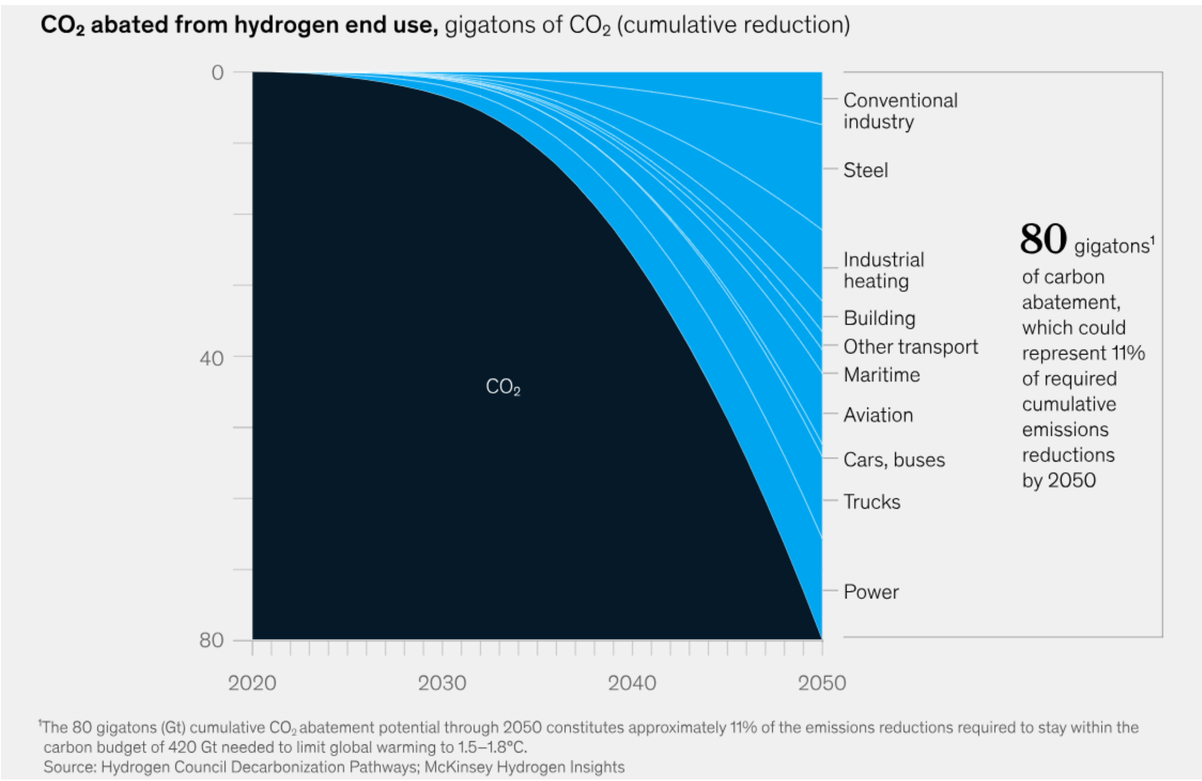


Figure 2: Hydrogen Decarbonization Potential, McKinsey Hydrogen Insights

To showcase the decarbonization potential of this colorless and odorless molecule, we created a hypothetical scenario where we are considering 3 medium-sized hydrogen facilities A, B, and C, producing each 5,000 kg of hydrogen daily. Facility A is producing grey hydrogen using Steam Methane Reforming(SMR). Facility B is producing blue hydrogen, using also Steam Methane Reforming but with 80% carbon capture and utilization or storage(CCUS). Facility C is producing green hydrogen using electrolyzers powered by renewable energy. 10kg of CO2 is emitted for each 1kg of hydrogen produced [10]

Facility A: emits 18,250,000 kg of CO2 annually (SMR with 0% reduction)

Facility B: emits 3,650,000 kg of CO2 annually. (SMR with 80% CCUS)

Facility C: emits 0 kg of CO2 annually. (Electrolysis)

This scenario considers only a few settings, not assessing methane leakage possibilities or fossil fuel used in powering the grid electricity, etc. The carbon dioxide emitted within the production phase is the main focus of this example. The potential of hydrogen in decarbonizing other carbon-intensive industries can also be examined by looking into the hydrogen lifecycle and its value chain distribution methods. Nevertheless, with only a few settings considered in medium-sized facilities, we demonstrated the large decarbonization impact of hydrogen[11]. Facility C using green hydrogen contributed to 18.3kt carbon reduction compared to Facility A, while Facility B contributed to 14kt of carbon reduction compared to Facility A (Figure 3)

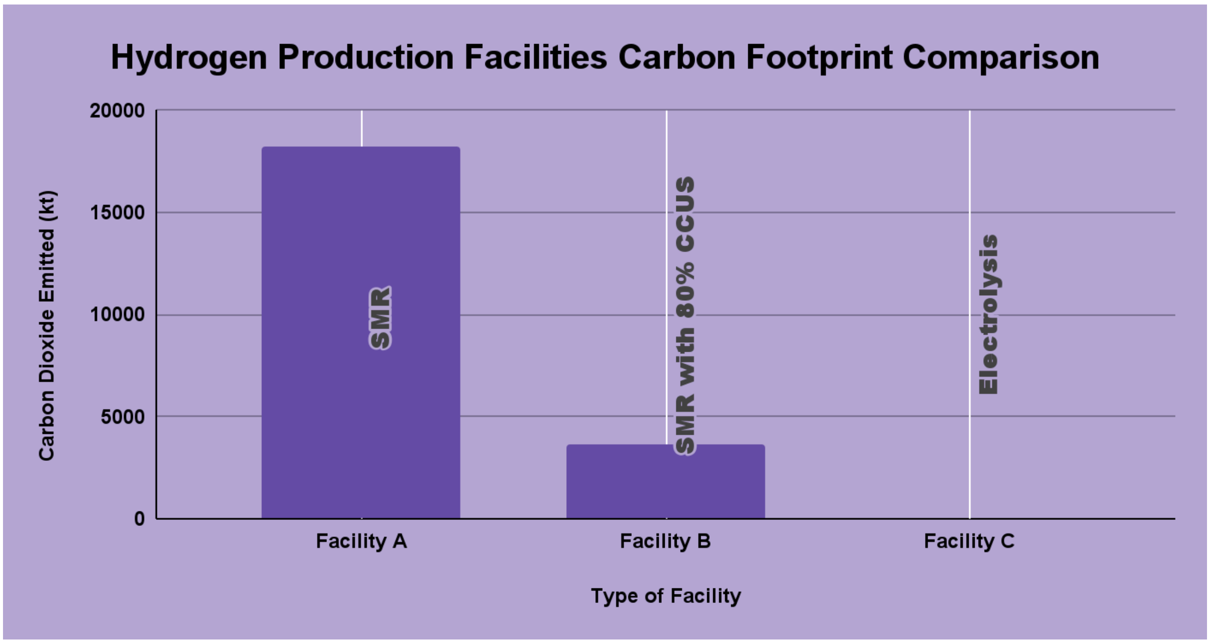


Figure 3: Hydrogen Production Facilities Carbon Footprint Comparison

This need for decarbonization is driving significant investments in this sector.

High Risk Investment

As of April 2024, 58 national hydrogen strategies and roadmaps have been published [12]. These published national strategies represent an indicator of the current and upcoming investments that could highlight the industry's potential. In some of the latest news, major investment plans are taking place in the Gulf Cooperation Council (GCC) countries [13]. In 2023, the hydrogen market size was estimated at USD 242.7 billion and is projected to reach USD 410.6 billion by 2030, with a CAGR of 7.8% between 2023 and 2030 [14]. However, with such massive investments comes high risk. This high risk is represented by stakeholders' hesitation and unwillingness to fully commit, due to the high costs and uncertainties associated with regulations [15].

Cost Uncertainties

The overall cost of hydrogen across its lifecycle is calculated using the Levelized Cost of Hydrogen (LCOH) [16], this method has its limitations and cannot be fully trusted since the price evolution of low-carbon and green hydrogen remains uncertain on its potential to decrease in the following years [17]. Even in regions with competitive renewable energy prices, green hydrogen is nowhere near the price of grey hydrogen [18].

Due to the uncertainties related to the monetary value predictions, there is a need to verify the green commodity to prove its price.

Need for Tracking & Certification

Based on the production method, hydrogen is classified using a color palette—grey hydrogen, blue hydrogen, brown hydrogen, turquoise hydrogen, etc [19]. While this classification indicates the production process, it does not provide information about the carbon intensity of the method or the distribution supply chain. Apart from green hydrogen, which is produced through electrolysis powered by renewable energy sources, making it carbon-free, there is yet no agreed-upon classification regarding the carbon intensity of the different production methods. Terms like low-carbon hydrogen or renewable hydrogen are not yet standardized definitions. However, progress has been made in that regard with the European Commission defining “renewable hydrogen” [20] based on the Renewable fuels of non-biological origin (RFNBO) requirements mentioned in the Renewable Energy Directive (RED II & III) [21]. Meeting those requirements will provide producers with Guarantees of Origin (GO), which have a certain monetary value and can serve as additional income for producers, which creates demand for higher-value products such as low-carbon hydrogen [22]. The problem is that setting up regulations takes time, and their adoption takes even longer.

The challenge is to create a verification system that proves the low-carbon/green hydrogen based on its carbon intensity and evaluates its monetary value with a price-competitive approach.

3. The "How"

Hydro-E Blocks is a blockchain-based Book and Claim solution designed to track and verify the origin of low-carbon/green hydrogen and its derivatives while monitoring CO2 emissions throughout the entire value chain. By leveraging a peer-to-peer system, we simplify the verification and allocation of green hydrogen credits through a 4-step process:

1. **Production and Certification**
2. **Book**
3. **Claim**
4. **Optimization (using AI)**

Our solution provides a transparent and trustworthy marketplace, ensuring secure and reliable transactions. This approach supports the growth of the green hydrogen market and helps carbon-intensive industries reduce their carbon footprint.

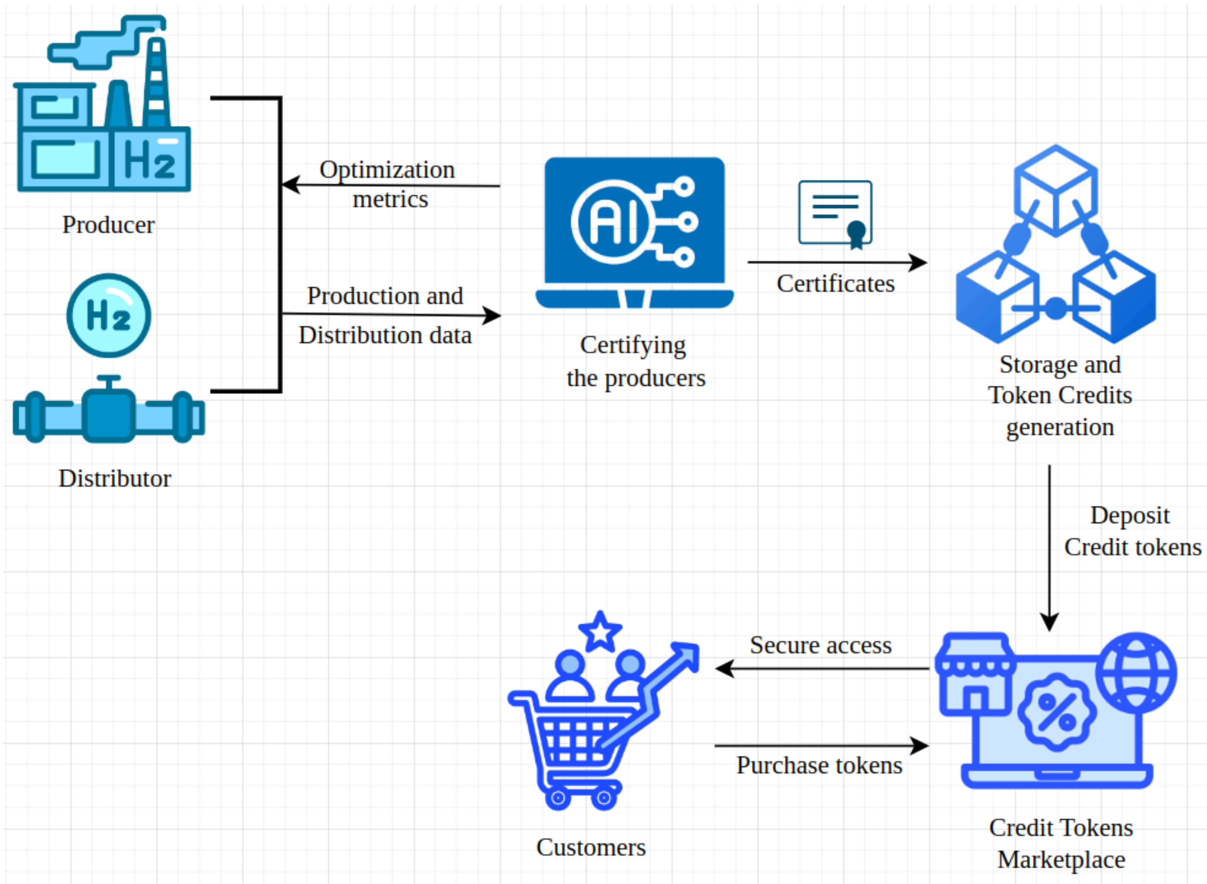
Technical Overview

Solution General Data Flow Architecture

Key Components:

- **Hydrogen Producers and Distributors**: These are the main stakeholders in the hydrogen supply chain, responsible for producing and distributing hydrogen.

- **AI-Based Certification**: The AI component analyzes real-time data from producers and distributors to assess the carbon intensity of hydrogen production.
- **Blockchain-Based Tokenization**: Blockchain technology certifies hydrogen producers by storing certificates and generating tokens that represent the certified hydrogen credits.
- **Credit Token Marketplace**: A decentralized marketplace where customers can buy hydrogen credit tokens, encouraging the consumption of low-carbon hydrogen.



The Solution Phases

Phase 1: Data Collection and Feature Engineering

- **Objective**: Gather and preprocess data related to hydrogen production and distribution.
- **Data Sources**:
    - Predefined production and distribution data from producers.
    - Data generated by our system using specific estimation and conventional algorithms.

- **Feature Engineering**:
  - Analyze data to extract key features, such as carbon intensity levels.

Phase 2: Certifying the Producer

- **Objective**: Use AI models to certify hydrogen producers based on the collected data.
- **Machine Learning**:
  - AI algorithms classify producers using metrics like carbon emissions and efficiency.
  - The AI model processes these features and outputs a certification level.
- **Certification and Blockchain Integration**:
  - Certified producers receive blockchain-stored certificates.
  - Each certificate is linked to a blockchain-based token that reflects the producer's contribution to low-carbon hydrogen.

Phase 3: Tokenizing the Credits

- **Objective**: Create and distribute hydrogen credit tokens for consumer purchase.
- **Token Generation**:
  - After certification, the system generates tokens equivalent to the low-carbon hydrogen produced.
  - These tokens are securely minted and stored on the blockchain.
- **Credit Tokens Marketplace**:
  - Consumers can purchase hydrogen credit tokens from the marketplace.
  - This marketplace incentivizes producers to lower their carbon intensity to sell more credits.

Phase 4: Optimization Metrics

- **Data Collection**: Producers and distributors provide production and distribution data to the AI system.
- **AI Analysis**: The AI identifies inefficiencies and areas for improvement.
- **Metrics Generation**: Optimization metrics are generated and shared with producers and distributors.
- **Implementation & Monitoring**: Producers and distributors implement optimizations while the AI system monitors progress.
- **Continuous Feedback**: The AI updates its models based on the new data, providing ongoing insights for further optimization.

Outcome

By implementing Hydro-E Blocks, we create a transparent, efficient, and trustworthy system that supports the growth of the green hydrogen market. This solution not only helps carbon-intensive industries reduce their carbon footprint but also drives down costs and builds trust across the value chain, ultimately accelerating the transition to a low-carbon economy.

Tokens Distribution mathematical logic :

First, let's define the quantity fraction.

Let's define θ : where $\theta \in [I0,\ I1,\ ..\ , I9]$, ***I*** is the carbon intensity level. Let's suppose that ***I0 < I1 < .. < I9***

Let's define the fraction where we make a ratio that quantifies the relationship between the quantity of hydrogen produced with a certain carbon intensity θ and the maximum that can be produced from that specific type.

$$\frac{q_{\theta_i}}{Q_{\theta\max}}$$

The role of this ratio is to value the production of green hydrogen. As we know, the maximum production of hydrogen with minimum carbon intensity is always less than the production of hydrogen with high carbon intensities, from this fact and using this ratio we incentivize the producers to go more green-friendly in production.

Let's now define the real value α that we get from the AI model which quantifies the percentage of the " Green Friendly" hydrogen production.

$$\alpha_\theta \in [0,1]$$

Let's now Define the Weight function which calculates the sum of the fractions multiplied by the specific value α of the specific producer.

$$W = \sum_{I=0}^{I=9} \sum_{i=0}^{i=n_I} \frac{q_{I_i}}{Q_{I\max}} \cdot \alpha_{I_i}$$

After calculating the sum, we need to calculate for each **θ** type the amount of tokens to distribute knowing that we have already defined a total number of tokens per day **r.**

The number of tokens for each **θ** type for each Producer is defined with :

$$N_{\theta_i} = \frac{\left(\frac{q_{\theta_i}}{Q_{\theta_{\max}}} \cdot \alpha_{\theta_i} \cdot r\right)}{W}$$

Verification :

We can verify the results by summing up all the Tokens distributed, the sum has to match r.

$$\sum_{I=0}^{I=9} \sum_{i=0}^{i=n_I} N_{I_i} = r$$

4. Roadmap

- **Research and Validation Q1:**
  - Validate Proof of Concept: Confirm the feasibility and potential of Hydro-E Blocks solution through research and analysis
  - Partnership with research labs
  - Refine the solution's value proposition and identify key benefits for stakeholders through conducting stakeholder interviews and surveying to gather feedback and insights
- **MVP Development and Advanced Data Analytics Q2:**
  - Develop a Minimum Viable Product (MVP) of the Hydro-E Blocks solution
  - Begin developing Advanced Data Analytics capabilities to provide valuable insights to stakeholders
- **Pilot Testing and Certification Q3:**
  - Conduct pilot testing of the MVP with a small group of stakeholders to gather feedback and ensure compliance with existing and emerging regulations
  - Obtain Necessary Certifications to gain credibility with industry stakeholders
  - Analyze pilot testing results and refine the solution further
- **Scaling and Adoption Q4:**
  - Refine the Hydro-E Blocks solution based on pilot testing results and certification requirements

5. Team

We are a dynamic research team of students, and each one of us brings unique skills and a shared commitment to making our vision a reality. Together, we're working to prove that we can intersect Blockchain Technology with the hydrogen industry.

- **Marwen Chaabouni:** Energy Specialist
- **Mohamed Ben Kedim:** Blockchain Engineer
- **Islem Hamzaoui:** Data Analyst
- **Ranya Ouni:** Front End Developer
- **Stephan Kermer:** Business Advisor

6. Conclusion

Summary of the project

Hydro-E Blocks is introducing a blockchain-based Book & Claim solution to the hydrogen industry, making it easier to verify and allocate low-carbon hydrogen credits. By offering a transparent platform, we're enabling stakeholders to make better decisions, lower costs, and establish trust throughout the supply chain.

Call to Action

We are looking for partners in green/low-carbon hydrogen industries or sub-industries looking for means to decarbonize their value chain and/or research labs eager to collaborate on specific use cases and develop an innovative solution. We can provide a pilot project for specific use cases developed by a dynamic research team. We are looking for pre-seed investment or grants to accelerate the development and deployment of our innovative blockchain solution for green hydrogen.

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