HydroLink Technical Whitepaper

Infrastructure to accelerate green hydrogen feasibility

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Abstract

Green hydrogen is created through the process of electrolysis, which uses renewable electricity to split water into hydrogen and oxygen ($2H_2O \rightarrow 2H_2 + O_2$). Hydrogen gas ($H_2$), unlike electricity, is combustible, storable, and can be transported. The primary sectors of the economy reliant on such properties include the industrial, chemical, and transportation industries. These sectors act as the hydrogen industry's prospective growth drivers, and, subsequently, will play vital roles in the global energy mix.

Green hydrogen currently represents 0.1% of hydrogen production globally, though projections indicate it could supply up to 25% of the world's energy needs by 2050. For green hydrogen to become a commercially viable renewable energy solution, certain barriers restricting commercial adoption, including production costs, supply chain inefficiencies, and inadequate regulatory systems, must be addressed.

This paper presents three use cases that have been developed to accelerate the feasibility of green hydrogen. Firstly, HydroLink proposes the integration of advanced technologies to optimise production efficiency. Secondly, supply chain transparency (HydroLink's Green Hydrogen Certification) enables efficient sectorial resource allocation and incentivises capital market participation. Lastly, a global voluntary carbon credit marketplace will enhance market efficiency through liquidity and pricing protocols.

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1 Introduction

The supply chain, or lifecycle, of a good, can typically be described as follows: the good is produced, used, and remnants of the good in question are disposed of. In a linear supply chain, individual participants generally have a limited view of the entire supply chain, in that they only interact with the parties they are in direct contact with — one step upstream and one step downstream. Further, within the energy industry, the current lack of transparency contributes to unpredictable lead times, energy shortages, and, in the case of gas leakages or safety risks, time wasted tracing logistics issues with slow and inaccurate systems.

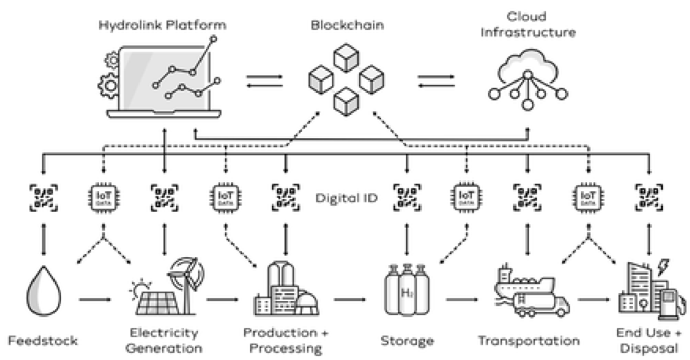
A blockchain-enabled supply chain allows for a shared, single view of the data, enabling a transparent supply chain – all parties have visibility, and the authenticity and provenance of goods are ensured, which is particularly important when applied to homogenous goods such as hydrogen gas (H_2). Though in this setting, end-users receive a homogenous, or pure, good, upstream processes could impact a consumer's perception of the good's value and consequently affect a consumer's or market's willingness to purchase.

At the end of the production chain, it is virtually impossible to verify the origin of - or methods used in the production of - hydrogen gas (H_2). Whether coal, natural gas, or renewable sources have been used in the production process, the resulting product is ultimately hydrogen gas (H_2). Wider industry adoption of green hydrogen as a viable energy solution will be severely restricted without a trusted method of verification that truly 'green' processes have been employed across the entire hydrogen production and supply chain.

HydroLink's ledger will provide data access to market participants, and power the 'HydroLink Network'. Certification-relevant data - entered from all stages of the hydrogen value chain - will be digitised to provide a full history of the location, time of production, distribution, and emissions produced relating to the hydrogen gas (H_2) in question. As the hydrogen continues its journey through the supply chain, from production plants, storage facilities, and distribution networks, to the end-user of the hydrogen. Each entity records and relays information regarding the processing and handling of hydrogen to the blockchain. Not only do consumers gain a fully transparent view of the origin of their energy, but producers and other participating vendors involved with the supply chain will be able to verify supply chain processes undertaken prior to their involvement.

Figure 1 illustrates the functioning of HydroLink's technological infrastructure across the green hydrogen supply chain:

Figure 1: HydroLink Track & Trace



2 Blockchain & Token Economics

The most prevalent and simple associated use case for tokens is for payment, however, tokens can be created and utilised within applications running on the network for more complex functions. The two types of tokens can be differentiated based on their fungibility.

2.1 Fungible Tokens

Tokens that are used as a method for payment are an example of fungible tokens. Fungible tokens can be replaced by another token of equal value. The capabilities of fungible tokens have expanded the way in which tokenised systems can be applied. Far beyond the 'store of value' use case, fungible tokens can administer governance rights, represent securitisation and ownership, and can be integrated into existing protocols enabling blockchain accessibility.

To access any HydroLink applications, a user will be required to either hold HLINK tokens (households) or pay a fiat currency licensing fee (producers) which will be converted to HLINK by HydroLink. The token is not only an 'access' utility token but also will serve as the primary medium of exchange. The token employs a transaction fee where a small number of tokens are 'burnt' and are effectively removed from the circulating supply. HydroLink's transaction tax and deflationary supply-side model were developed to prevent trader speculation, improve long-term price stability, drive price appreciation, and offer an effective hedge against inflation. HLINK demand will be generated through two primary methods:

- Token purchases and exchanges with fiat currency to gain access to HydroLink applications, and
- Token purchases to exchange digital assets or services via the HydroLink platform
- HydroLink token ‘buy-backs’ on a regular basis.

2.2 Non-Fungible Tokens (NFTs)

Tokens that can be identified by unique characteristics, often a representation of a specified asset, are an example of non-fungible tokens (NFTs). NFTs are often implemented to represent real-world assets - such as real estate shares, gold, or art - which can be transferred over the network and between owners, with payment if required, making the transaction’s occurrence immutable, and mitigating lengthy transfer processes.

Generally, multiple entities are participants in the complete manufacturing supply chain of a product. That said, the same mechanism of changing ownership of NFTs between counterparties and attaching data to the NFT in question as it moves through the supply chain can be utilised in more complex supply chain operations. While blockchain facilitates the technology required to track products progressing through the supply chain, manufacturers may require internal tracking for the NFT representation of procured materials within their facilities. This empowers them to accurately document where, and in what products, the materials in question are being used.

A completed product composed of multiple different materials can be affiliated with several NFTs, each comprising a transparent and thorough history of each individual material’s passage from its first introduction into the supply chain.

A token can be used to virtually represent a physical object, such as a shipment of hydrogen gas (H_2). As it moves through each stage in the supply chain, valuable data points such as temperature, geolocation, and ownership can be captured and published on the blockchain. These data can be classified using the following fields:

ID (string)	unique identifier within HydroLink Ledger
Available Assets (float)	lists all environmental & transactional information
NotForSale (boolean)	boolean flag: set to FALSE if for sale (i.e., carbon credit)
Owners (string)	token owner
Buy (string/hashmap)	a transaction settlement that is denominated in HLINK
Notes (string)	placeholder for additional information specific to the asset

Smart contract functions and mechanisms can be developed for business-specific purposes. In this case, the recording of environmental and transactional data will be used to improve the information efficiency of market participants, ultimately improving economic efficiency.

By taking advantage of blockchain technology to track NFTs, retrieval of these data becomes decentralised, permitting any of the supply chain's contributing parties to own and refer to these data. If the network members decide to make specific data publicly accessible, environmentally concerned consumers can examine the blockchain and follow the product's chain of custody, tracing its path through the supply chain.

3 Green Hydrogen Production Optimisation

Hydrogen fuel is produced through a process of water electrolysis. If the initial energy used is derived from a renewable system, the production method is described as 'green'.

Renewable electricity can supply a significant portion of the energy mix. However, there are primary sectors of the economy reliant on the properties which differentiate hydrogen gas (H_2) from electricity, which has many limitations. The primary sectors of the economy which are reliant on such properties include the industrial, chemical, and transportation sectors.

3.1 Problem Identification

For sector demand to be met exclusively by renewable green hydrogen - and thus for green hydrogen to become widely adopted - total production costs need to drop below $2/kg. Reaching this price point requires reducing both capital investment (CAPEX) and operational costs (OPEX). Three cost components of the green hydrogen lifecycle need to be addressed:

- Electrolyser efficiency;
- Cost of renewable electricity generation; and
- Production plant installation and operational costs.

In the next five to ten years, it is estimated that renewable hydrogen costs could drop to approximately $1-1.50/kg in optimal locations, and roughly USD $2-3/kg under average conditions.

3.2 Data-Driven Operational Efficiency

The Internet of Things (IoT) refers to computing devices that connect wirelessly to a network and can transmit data from a physical data source. The embedded technology in IoT devices translates data from physical and non-internet devices. Devices can then execute functions related to these data to visualise, engage or otherwise enable stakeholders to make decisions based on the output. IoT devices can interact amongst themselves, and the collective pool of data can be used to algorithmically determine outcomes.

Data integrity is ensured with globally certified IPv6 compliant IoT mesh networking protocols with no single point of failure. This will ensure that producers - as well as other users - experience lossless data transmission. It will streamline connectivity to producers' cloud-based, entity-specific data storage. Once this data has been processed, the end-data e.g. the certification of origin outcome and certificate will be stored as an NFT document on our block-chain.

3.3 Process Efficiency: creating actionable insights

These data will be captured in contracts that will be triggered and stored on an immutable blockchain. Our producer key performance indicator (KPI) dashboard will reflect three technological focal points - business insights, digital twins, and operations monitoring.

3.3.1 Business Insights

Analytics can transform data into business intelligence through KPIs. For green hydrogen, data obtained from production plants, storage and distribution networks, energy off-takers, and weather, can provide corrective action recommendations to maximise yields. Energy losses can be prevented by forecasting failures and optimising electrolyser uptime, ultimately increasing revenues, and decreasing OPEX.

3.3.2 Monitoring

Managers can observe real-time production analytics and control of assets remotely. Lowering energy consumption and improved employee management can lead to 10-20% operating cost reductions. Leveraging monitoring models with KPIs such as energy consumption, production rates, and equipment performance allows operators as well as investors to view cost and revenue forecasts and, if required, make strategic decisions to optimise returns. IoT with remote monitoring capabilities enhances safety measures through rapid anomaly detection using intelligent alarms and sensors to monitor asset health.

3.3.3 Digital Twins

Digital twin technology can be used to maximise the return of investment and minimise project risk. The testing of virtual representations of the physical environment in various ‘scenarios’ – such as weather conditions, demand volatility and current (or future) infrastructure, can be used to optimise the three lifecycle phases – design, build and operation.

Estimations suggest that digital twin technology can optimise capital expenditure (CAPEX) by 10-15% along with a marginal change in operating expenditure (OPEX) by 30-50%. Digital Twin will influence how the design, build, and operations of a device are constructed in a single lifecycle, which comprises three phases – design, building, and operation. Most notably, the DT feedback aids producers in real-time by improving the operation of the H_2 production device, based on current information. Further, the collected feedback facilitates the better design and improved manufacturing by the lessons that are learned and the recalibration that has taken place along the way.

4 Green Hydrogen Certification

The HydroLink Platform will offer green hydrogen certification to consumers and supply chain participants. The report will comprise two core elements: environmental impact audits and transactional audits. First, environmental impact audits will be used to assess the sustainability practices employed in the production of green hydrogen. Secondly, transactional audits will be utilised by other participants in the supply chain to certify the exchange of hydrogen between counterparties. Downstream suppliers, distributors and end-use consumers can utilise the network to ensure that each stage in the supply chain is following social and environmentally preservative practices.

4.1 Problem Analysis: industry-specific challenges

At present, an end-user cannot with any certainty delineate the origin of a unit of hydrogen. Whether coal, natural gas or renewable sources have been inputs in the production process, the result is simply hydrogen. Early industry adoption will be primarily driven by companies, organisations, or governments opting to pay the higher price, which aligns with their social commitments and statutory obligations to climate change mitigation. Without trusted certification that their supply of hydrogen has been produced with limited carbon emission, industry uptake will be restricted. There is little incentive for firms to re-engineer their business model around the pursuit of green hydrogen if there is no consistent metric being used when adjudicating their practices.

4.2 Methodology

GHGs can be emitted and removed throughout the life cycle of a product which includes the acquisition of raw material, design, production, transportation/delivery, use and end-of-life treatment. Quantification of the carbon footprint of a product (CFP) will assist in the understanding and action to increase GHG removals and reduce GHG emissions throughout the life cycle of a product. This document details principles, requirements and guidelines for the quantification of CFPs.

HydroLink's GHG emissions accounting procedure utilises emission protocols and the internationally recognised standards derived from the International Organization for Standardization (ISO) to assess the carbon footprint (and other impacts) of fuel production. IPHE adopted three of the eight principles defined in ISO 14040 (environmental management - life cycle assessment (LCA)).

- Goal and scope phase (ISO14067)
- Life cycle inventory (ISO14040
- Lifecycle impact assessment (ISO14044)

4.2.1 Principle 1: goal and scope

- Product category and investigated pathways are consistent;
- System boundary is equivalent;
- Data quality of inputs and outputs are consistent; (coverage, precision, completeness, representativeness, consistency, and reproducibility); and
- GHG emissions and GHG removals are treated identically.

4.2.2 Principle 2 & 3

The following criteria shall be applied for the life cycle inventory and LCIA phase:

- the methods of data collection and data quality requirements are equivalent;
- the calculation procedures are identical;
- the allocation of the flows is equivalent; and
- the applied GWPs are identical.

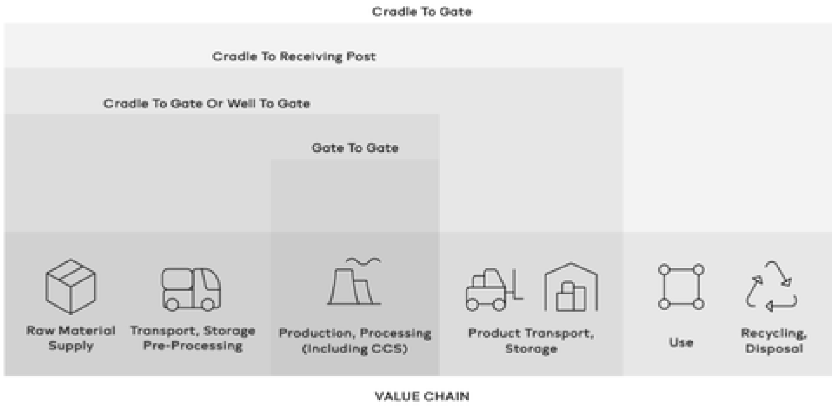
4.3 Reporting Framework & Boundaries

As part of the methodology devised by the IPHE, production boundaries will be defined. This indicates which stages of the hydrogen production value chain will be subject to GHG emission monitoring. As taken from the report, this methodology is based on the principles of:

- inclusiveness (methodologies should not exclude any potential primary energy);
- flexibility (approaches must allow for unique circumstances and hence flexible);
- transparency (methodologies must be transparent in approach and assumptions to build confidence);
- comparability (approach should be comparable with the approach used by other technologies to help allow for 'apples to apples' comparisons on emissions); and
- practicality (methodologies must be practical, facilitating uptake by industry and use in the market).

Referring to *Figure 2*, the 'well-to-gate' boundary is seen by IPHE stakeholders as the preferred starting point in defining the system boundaries.

Figure 2: System Boundaries



The 'well-to-gate' boundary would encompass all GHG emissions emanating from the collection of raw materials, transporting them for pre-processing, and final good production. It excludes elements of the value chain beyond production, such as the transportation of hydrogen to consumption sites, its use, and its end-of-life treatment.

The environmental impact caused by the construction, manufacture, and decommissioning of goods, peripheral assets held by the firm in question, business travel and employee commuting is not considered within these boundaries. The logic behind this reduced scope of the Hydrogen procurement process is largely driven by the relatively minor emissions resulting from these practices relative to the emissions associated with the production process itself for both renewable and non-renewable hydrogen. These effects are expected to decrease substantially as technology advances and the upstream material inputs for Hydrogen production (aluminium, copper, and steel among them) are decarbonised in their respective sectors.

4.4 Environmental Audit: production data scope

To leverage the benefits of the HydroLink platform, hydrogen producers will connect pre-configured IoT devices to their production equipment. Sensory equipment is capable of accurately recording geolocation and environmental conditions - including temperature, humidity, and pressure levels. Dedicated embedded algorithms will parse the raw physical machine data, and subsequently, compare it against the standardised data pool. The design of the parameters embedded in the smart contracts will execute in accordance with the globally recognised IPHE emission standards. A summary report of these interactions is generated and recorded on the blockchain, providing exhaustive referential data, which companies can use to refine and optimise their practices. Further, IoT devices across the stages of the supply chain that are excluded from the IPHE recommended guidelines will be subject to traceability.

4.4.1 Electrolysis

As described in section 4., an electrolysis cell contains an anode and a cathode separated by a membrane and immersed in a conductive solution - or an electrolyte solution.

Currently, there are three primary electrolyser technologies deployed - the alkaline electrolyser, polymer electrolyte membrane (PEM) electrolyser, and solid oxide (SOEC electrolyser). These processes can be differentiated by how the electrolyte is used, and the resultant production temperatures.

Using a direct current power supply, electricity flows through the electrolyte solution to drive a non-spontaneous reaction in water causing water molecules to split into hydrogen and oxygen molecules. Each electrolyser system comprises a stack of electrolysis units, a gas purifier and dryer, and a cooling apparatus.

The magnitude of greenhouse gas (GHG) emissions produced during electrolysis is determined based on the fuel source used for the catalysing electricity supply. Hydrogen isolated via electrolysis reliant on the combustion of gas, liquid, or solid fuel sources, make up most emission sources in the production process. However, if the initial energy stimulating electrolysis is derived from a renewable system, clean, or "green", Hydrogen can be produced and certified as such. Based on these parameters for emissions accounting, electrolysers are generally assumed to possess an outlet pressure of 3 MPa.[16]

4.4.1.1 Emissions Sources in Electrolysis

GHG emissions resulting from electrolysis are contingent upon the nature of the supplied electricity for the process, as it can be sourced from power generated on-site using combustion methods for liquid, gaseous, and/or solid fuels, or supplied from an off-grid on-site system.

4.4.1.2 SMR/CCS Process Description

The steam methane reformer (SMR) is the most used technology for Hydrogen production from natural gas, or light hydrocarbons, in the current market.

In SMR facilities, GHG emissions are created through the combustion of fossil fuels for heat and steam, and because of the reforming reaction. Modern implementations of this technology have allowed hydrogen production facilities to experience significantly improved efficiency in CO_2 emission reductions.

Synthesis gas, or syngas, is a gaseous fuel mixture consisting predominantly of hydrogen, carbon monoxide, and often some remaining carbon dioxide from the pre-capture process. Syngas is used as an intermediate stage in the production of synthetic natural gas, a form of gas created from coal that can be used as a substitute for natural gas and is capable of transmission in natural gas pipelines.

De-sulphurated natural gas is heated, mixed with steam, and channelled through a steam reformer, producing synthetic gas. This catalyses an increase in the percentage of hydrogen in the synthetic gas mix prior to purification, resulting in isolated hydrogen. For both of these approaches - with carbon capture systems implemented - the CO_2 compression needed for Carbon Capture and Storage (CCS) represents a sizeable emissions point in concurrence with the upstream emissions necessary to procure natural gas and coal.

Reductions in CO_2 emissions beyond this point would only be feasible with the introduction of CCS. There are three basic types of CO_2 capture: pre-combustion, post-combustion, and oxyfuel with post-combustion. Pre-combustion processes are designed to convert fuel into a gaseous mixture of CO_2 and hydrogen, with the hydrogen being separated and burned without producing CO_2 (which can be compressed for storage or transportation). Carbon Capture and Storage systems typically consist of:

- Feedstock pre-treatment
- Pre-former
- Primary reformer
- High-temperature shift reactor
- Pressure swing absorption (PSA)

The industry standard for CO_2 capture from an SMR H_2 plant involves emissions capture from the shifted syngas using Methyl diethanolamine (MDEA) solvent. Other CO_2 capture options can be integrated, including the capture of CO_2 from PSA's tail gas using MDEA, the use of Cryogenic and Membrane Separation, and the capture of CO_2 from flue gas using MDEA. These options involve the CO_2 capture rate in the range of 56% to 90%.

The conversion processes required for pre-combustion capture are more complicated than those involved with post-combustion, making the technique challenging to adopt and implement for established power plants. Post-combustion processes segregate CO_2 from combustion exhaust gases. CO_2 can be captured with a liquid solvent or using other separation methods.

In an absorption-based approach, after the CO_2 has been absorbed into a solvent it is released via heating to create a high-purity CO_2 stream. This technology is ubiquitously used to capture CO_2 as an input for the food and beverage industry. Oxyfuel combustion processes utilise pure oxygen rather than air for the combustion of fuel. This results in exhaust gas that is largely water vapour and CO_2 that can be further captured, purified, liquified and commodified.

4.4.1.3 Emissions Sources in SMR/CCS

For steam methane reforming with CCS, the main source of GHG emissions is the conversion of natural gas (NG) to CO_2. Other significant emissions sources include the scope 2 emissions of grid electricity, CO_2 removal, and CO_2 compression for CCS.

4.5 Certification Document & Reporting

The certificate of origin can be made publicly accessible, ensuring compliance and producer accountability - this will be invaluable in increasingly emissions-conscious markets. The certification issued by HydroLink will relate to a unit tonne of hydrogen and include the following information:

- The level of associated GHG emissions emitted by the production of the hydrogen;
- The location, name, and ownership of the production facility;
- The technology type used to produce the hydrogen; and
- The primary fuel and energy source used during the process (natural gas, coal, renewables etc.)

5 Carbon Credit Marketplace

The HydroLink platform will lay the foundations for companies to balance their carbon budgets reliably and securely. An emissions accounting system will measure a firm's emission output compared to the carbon offsets they have created. Carbon offsets are generated from operations that actively reduce carbon emissions – such as a renewable energy facility or efficiency optimisation strategies e.g., insulating buildings to decrease heat loss.

The resultant carbon offsets can be quantified and exchanged in the compliance market or the voluntary market. Compliance markets are regulated by national or international carbon reduction schemes. Voluntary markets enable entities to purchase offsets created in the compliance market - otherwise known as 'voluntary emissions reductions' (VERs).

5.1 Problem Analysis: Market Failure

The compliance and voluntary markets are both characterised by incorrect carbon ratio parameterisation. Market inefficiencies have led to widespread double-counting and the erroneous valuation of the environmental impact of offsets, creating counterproductive market and pricing imbalances. Furthermore, there is limited availability of market registries that provide customers with a way to verify the authenticity of their assets, contributing to fraud and inaccurate reporting.

Market inefficiencies have led to severe undervaluation of environmentally conscious operations. Consequently, the reduced incentive to offset emissions, save energy, and purchase renewable energy has restricted industry uptake of green hydrogen and threatens to dampen market participation in future years.

5.2 Solution

The application of blockchain technology can be used to address the aforementioned market inefficiencies. The HydroLink ecosystem will provide a transparent, immutable, and secure ledger to improve reporting standards and processes. HydroLink's members can provide additional levels of data - stored on the HydroLink supply chain ledger for applications discussed in *Part 3* & *Part 4* of this document. The operational attribution of each shipment of hydrogen can prove, with unprecedented precision, how carbon-intensive (or negative) the process was. The tokenisation of the carbon offset market presents a solution to ownership tracking, market liquidity, and cross-market integration. Data integrity must be incentivised to improve market confidence in the quality and standards of credits.

HydroLink will utilise a multi-version concurrency control (MVCC) to prevent double-spending. This means that when multiple operations try to update the same key simultaneously, all but one update will fail. If two sellers attempt to transfer value to the same token, only one of the transfers will be successful. In the process of creating an NFT, the algorithm creates a unique transaction ID ensuring no duplicate keys can exist.

Contention is a consideration whenever two processes seek to update a common resource and thus is inherent in any account-based implementation. This limitation can be addressed by queuing transactions. The application would queue the processing of transactions for endorsement and ordering and postpone processing of other transactions that update the same key until the first has either been completed or failed. An automated compliance checking mechanism will be added to check against a registry of approved methodologies. This approval will take the form of a cryptographic signature from the standard's body within the metadata of a token.

6 Technology Overview

6.1 Identity & Access Management (IAM)

Platform access requires identity-based policy documents to be attached to an identity, such as an IAM user, group of users, or role. Policies control what actions users and roles can perform, on which resources, and under what conditions. Access control lists (ACLs) are then used to assess the user's right to perform an action. Accordingly, users will be categorised into one of the following three groups.

6.1.1 Regulatory Bodies

Regulators have the highest level of system visibility. Entities that can be classified as a regulator will be energy/industry safety associations, national and state governments, and various official organisations.

6.1.2 Members

Members have significant control over their data. Additionally, application functions offer data-driven business insights, such as live data monitoring of the user's operations.

6.1.3 Consumers

The application enables customers to assess company performance and view published data. This will be measured against ESG benchmarks to improve stakeholder transparency and promote environmental accountability. For example, the summary information which is presented on a hydrogen certificate of origin can be viewed. As information availability is a key driver in company publishing on the public network, consumers are not required to submit identity documents - the information available is purposed for public viewing.

6.2 Decentralised Identifiers (DIDs)

A DID is a verified digital identity used to identify any subject - such as a non-tangible asset, a person, or an entity. Unlike traditional forms of identification, DIDs are not generated by a central authority and are stored in a decentralised database. A DID for a given system resides in a decentralised DID registry or on a blockchain network, which in this instance, will be the HydroLink Ledger.

Companies or individuals, such as those producing hydrogen, operate the digital twins of various assets in private trusted networks. A digital twin represents all relevant aspects of the physical asset in a digital setting. The assets and their digital twins are unambiguously discoverable in an open digital ecosystem, and while many digital twin networks currently operate in centralised networks, our decentralised approach will negate their disadvantages. Registering a digital twin can be done via submission of a DID document, which is stored as a transaction in a common dataset and accessible via a unique asset ID. Asset operators will be able to connect to the network of nodes and find the corresponding transaction in the dataset, allowing for the DID transaction to be extracted. The DID document, processed via data parallelism, can then be accessed from outside the HydroLink Ledger.

6.3 Verified Credentials (VCs)

The main difference between traditional, non-digital credentials and verifiable credentials are the way they are verified. Traditional credentials require manual verification, such as a signature or stamp. Verifiable credentials use a digital proof mechanism, such as a digital signature. A digital cryptocurrency wallet, such as MetaMask, is used to verify ownership through a digital signature. Blockchain technology, through the embedded mechanisms of trust, negates the need for any interaction between the issuer and the verifier.

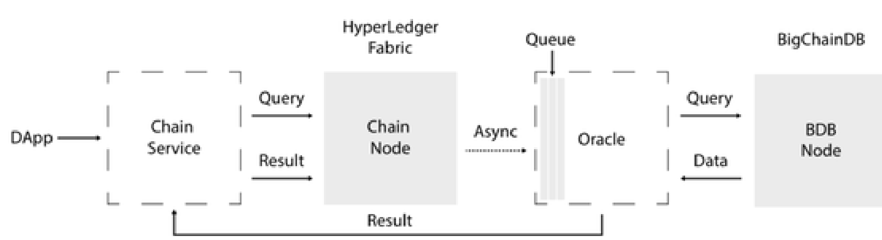
Once an authority verifies a claim, a VC can then be used as an official record to assure others of the truth of statements made. These credentials are linked back to the credential subject's digital identity and recorded on the user's DID document. A DID document can contain a detailed set of VCs that illustrate the origin, attributes, and capabilities of a subject. For example, account registration for a hydrogen producer will require:

- A scanned copy of the application user's business license and company registration;
- Hydrogen production equipment list and approved third party inventory audit;
- List of raw materials (pre-processing) for hydrogen production and their associated GHGs emissions; and
- Production capacity, storage, location, and other summary data points;

7 Technology Infrastructure

The HydroLink Web3.0 Application is designated as the main platform for business and government use. The decentralised business logic of Hyperledger Fabric can be integrated with a decentralised and producer specific data storage. The integrated solution (illustrated in *Figure 3*) will provide a set of decentralised databases that can be written to and queried from directly, in the most efficient and secure way. This will enable non-discriminatory data processing, ensuring that no producer can tamper with the data output of their physical devices. This will enable a clear understanding of the certification of origin process in addition to the certification of the supply chain and having data that are unfettered to enable the development of an automated carbon credit market.

Figure 3: Technology Stack



7.1 Front-end

HydroLink will build the web application with React, using a server-side rendering React framework - Next.js - for front-end development.

7.2 Chain Service

A chain service will be used to interact with the smart contracts on the private blockchain network. HydroLink will use hybrid smart contracts to ensure the secure delivery of enterprise data through trusted execution environments, while also abstracting away the technical complexities of executing on-chain transactions.

7.3 Chain code: Hyperledger Fabric

Hyperledger Fabric (Fabric) will be used to build the data retrieval system. Fabric offers a customisable development environment to program chaincode - also known as smart contracts. In general, chaincode contains the business logic to achieve our business purposes. Business logic contains data manipulation (computation) from physical devices (as input arguments) to output.

7.4 Oracle

An Oracle is a critical tool for supplying smart contracts with environmental data from sensor readings, satellite imagery, and advanced ML computation. An input oracle will fetch data from real-world (off-chain) databases and deliver it onto the HydroLink blockchain network for smart contract consumption and processing.

8 Conclusion

In this paper, HydroLink models a tokenised economic system that is built on blockchain-based technology architecture and applied to a highly complex, vital supply chain - hydrogens. The HydroLink Network will deploy this model to enable organisations to observe the provenance, authenticity, and carbon footprint of their energy consumption, as well as ensure sustainability standards are upheld by the supply chain participants.

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