Executive Summary

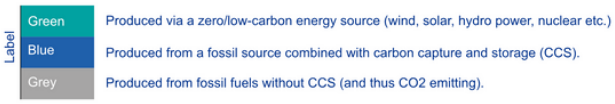
Hydrogen is the most abundant element on earth, and it has a history of being used for energy. In the 1950s, NASA used liquid hydrogen as rocket fuel — and today, the industrial gas is commonly used in petroleum refining and fertiliser production. Hydrogen has also recently gained attention for its potential to help decarbonise manufacturing, transportation, and energy. The molecule only emits water vapour when used as a fuel in hydrogen fuel cells, and it does not emit CO2 emissions when combusted. The colours of hydrogen (grey, blue & green) are crucial for the energy transition to low-carbon economy because each production pathway generates different amounts of greenhouse gas emissions. As energy systems increasingly evolve from centralised to decentralised, from "grey" to "green," stakeholders will need to efficiently account for and track emissions and green molecules in a transparent, secure, and standardised way, and must be able to do so along value chains - generation, storage, transport and consumption. Decentralised tech such as blockchain could be part of a viable solution framework for this critical carbon accounting problem.

Why Hydrogen Matters ?

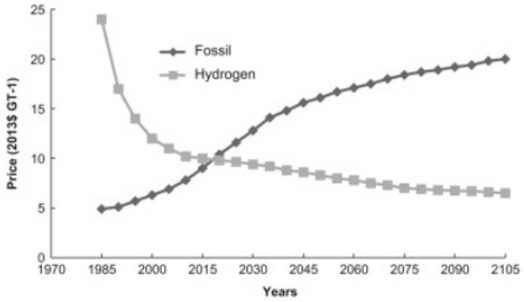
With mounting government regulations and investor pressure to decarbonise, manufacturing, energy, and transportation companies are increasingly turning to hydrogen to reduce their carbon footprints. For manufacturers, hydrogen is the de facto energy source that they will use to decarbonise their operations. *While solar and wind could help decarbonise the grid, current methods to harness them cannot generate energy* ***densely*** *and consistently enough for manufacturing operations*. Hydrogen, however, can fuel the high-temperature manufacturing operations related to steel, glass, chemical, and cement. On-site, modular electrolysis facilities are particularly appealing for factory sites, as they eliminate the high hydrogen distribution costs. The global hydrogen market is expected to more than double from below 100 Mt today to 223 Mt by 2050. Low-carbon hydrogen will both displace existing fossil-intensive demand and create new markets

Colors of Hydrogen

Hydrogen is given different 'labels' which reflect different methods of production. While the H2 molecules that are produced are the same, the label relates to the source.



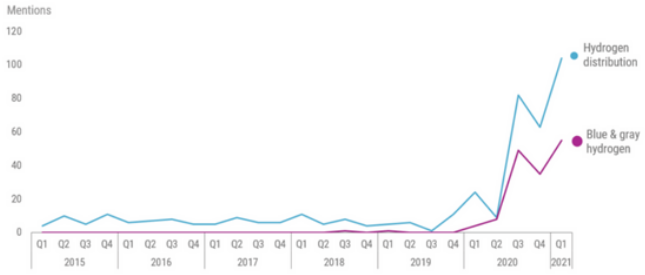
The accessibility of green hydrogen is linked to the availability of low-carbon energy sources (wind, solar & hydro power). Current projections suggest that the rearrangement of the value chain from grey to green hydrogen is unlikely to occur at scale before the 2030s. As demand for low-carbon (green) hydrogen is still low (<1Mt), CAPEX/kW (840 USD/kW) requirements are high for producers, most of which are being passed to the consumers at a higher cost (USD/kg), further muting the demand. It's worth noting that fuel cells powering electric cars or power sector isn't the principle consumers of industrialised H2. By 2025, **Ammonia** would account for 48% of H2 demand. As retail demand (car & power) picks up stimulated by growing awareness, global warming, regulation on CO2 pricing, green H2 is expected to become cost-effective by 2030 onwards. As manufacturing scales and becomes automated, electrolyser (generates green H2) CAPEX will fall 35-65% in the next decade, making sub US$2/kg green hydrogen achievable in most markets by 2040



However, substantial investments are required to accommodate the anticipated growth during the timespan of 2030-2050. Developers will need to invest around US$100 billion to support supply growth up to 2030 and an additional US$500 billion by 2050. As green hydrogen costs plummet, it would create at least a **US$600 billion** investable opportunity.

Tracking The Hydrogen Energy Mix

Analysing reports from quarterly earning calls it seems more and more executives are talking about H2 distribution and colours/forms.



Till the cost-advantage of green H2 becomes substantial, our world needs to live with H2 energy-mix while **progressively** (ref. Air Liquide's Q3'20 earnings call, by CEO Benoit Potier) transitioning to a 100% green H2. As energy systems transition progressively from centralised to decentralised, from "grey" to "green," stakeholders will need to efficiently account for and track emissions and green molecules in a transparent, secure, and standardised way, and must be able to do so along value chains from production to consumption. Additionally, as the market is far from commoditisation (cheaper green H2 as forecasted by 2030+), stakeholders must be appropriately credited for investing in the current premium required to produce carbon-free hydrogen. Therefore, the ability to verify a hydrogen molecule's origin from clean energy sources amidst a dynamic energy landscape presents both a sizeable challenge and a **tremendous opportunity.**

Decentralised Tech for H2 Provenance

Verifying H2 molecule's origin from clean energy sources amidst a dynamic energy landscape will require managing **large volumes** of multi-party transactions, which need to be settled quickly, securely, and inexpensively. Although blockchain may seem like an obvious option, huge storage and data exchange requirements of a blockchain network may be suboptimal to implement a H2 provenance infrastructure along with modest usage of IoT devices. Looking beyond blockchain, here are few alternatives for building a decentralised & regulated IoT and

energy-based supply-chain network

- DAG
- Hashgraph (Hedera)
- Holochain
- IOTA Tangle
- HyperLedger (permissioned) with fast consensus protocols such as Tendermint (or HCS) along with HyperLedger Grid

As Hydroverse has planned to develop a credential-based **marketplace** for various H2 ecosystem participants (producers, supply chain companies, regulators etc.) with potential deployments of many IoT devices, a scalable, fast & secure decentralised system is required supporting high throughput (TPS). DAG, HashGraph and Tangle (IOTA), although scale much better than traditional blockchain systems, fall short (TPS ~10K) of the volume usually required for a scalable energy marketplace with typical TPS ranging to millions of transactions per second (M TPS). It's worth noting that all alternatives listed above skips the "expensive" mining process inherent in PoW blockchains such as Bitcoin. As each node processes its own ledger, Holochain can achieve limitless scalability & TPS (>M TPS)

Why Holochain ?

To securely trace each step along the supply chain from generating, storing, transporting and adopting green hydrogen, a range of IoT-friendly cryptographic protocols (ex. lightweight block cipher) and a suitable (one that works under CPU & memory constraints with high scalability) decentralised network needs to be factored into the solution.

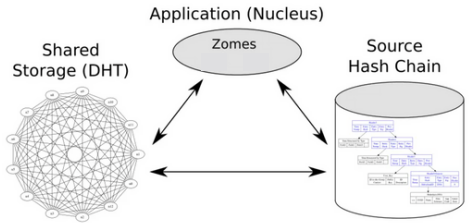
As each entity of a blockchain network stores all users' transactions in a chain, the memory requirements at blockchain entities escalate with increasingly longer chains (***Storage*** constraint). Another consequence of increasing transactions in a longer chain is that it requires a very large bandwidth and data sharing giving rise to security vulnerability (***Data Exchange*** constraint). The challenge is further exacerbated by the requirement of additional computational energy for mining and consensus algorithms. To validate any transaction in a blockchain, all the nodes will start mining and only the first node who is successful in the mining process will be allowed to validate the transaction. From the aspect of computational time, this is a complete wastage of time for the rest of the nodes who attempted the mining process but were unsuccessful. Hence, blockchain gives rise to redundant computational overheads for resource-constrained networks (***CPU*** constraint).

Holochain is an emerging technology that provides an open source distributed network infrastructure to communicate securely without inheriting the huge storage and data exchange requirements like blockchain. Holochain magically performs the task by combining two underlying techniques:

- distributed hash table (DHT)
- Hash chain.

DHT is focused on data propagation issues and hash chains are built to preserve data integrity. The most significant aspect of storing data in DHT is that the network doesn't become congested like the blockchain-based network does. The DHT of holochain allows the network to provide scalable performance (unlimited scalability). A typical transaction flow of a Holochain P2P network looks like this -

- **P2P Network**: Tx request is created and signed by Holochain agents in P2P network to store data in the private & local Hash chain
- **Communication**: Tx request is broadcasted to some selected peer agents
- **Validation**: Request is validated through peer validation based consensus using other agents' copy of hApp (Holo App; dApp) *rules*
- **Verification**: Verified Tx is accepted by peers and signed.
- **Publication**: Source hash chain is stored on selected peer agents through DHT



Source Hash Chain is what makes it possible for the hApp to work offline. It is a local ledger that each peer or agent can own. The data stored in the local chain needs to be signed before it can be merged with the global shared DHT. For example, if two parties interact with each other, they both need to validate it to their local source chain and then integrate it into the shared DHT. Idea that not everything requires to reach a global consensus is pretty simple yet revolutionary for **scalability**. Beyond scalability, other advantages include:

- Reduced Network Traffic & Data Exchange (via local chain & DHT)
- Low-Complexity Transaction Validation (No mining)
- Efficient Consensus Mechanism (no global consensus)
- Operating Time and Memory Efficiency
- Efficiency in Large-Scale Networks
- Configurability (via hApp's **DNA**; app-specific rules around privacy, governance etc)
- Security (addresses threats such as Illegal Data Tempering, MitM Attack, Malicious Code/Node). Moreover, custom privacy-preserving tech such as custom encryption, zero-knowledge proofs (ZKP), private source chain entries, private group spaces, app-level constraints on data etc, can all be used in a hApp.
- Multi-party Transactions (via DHT. By doing so, it creates a crossing of local source chains, which further helps validate the whole set of transaction)

Hydroverse's Potential

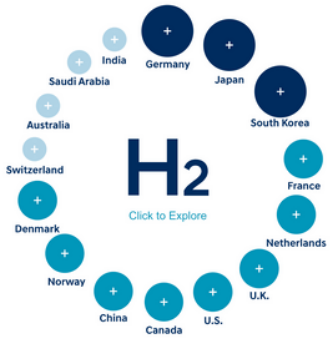
Is this a problem worth solving? Yes. As green H2 becomes commoditised (cheap) not until 2030, ability to verify a hydrogen molecule's origin from clean energy sources amidst a dynamic energy landscape presents a tremendous opportunity

Competitors in market

It's not a crowded market yet. Among few competitors, **ACCIONA** has developed GreenH2chain (Spain) allowing its customers access to a digital platform that will allow them to verify and visualise the entire green hydrogen value chain in real time and from anywhere in the world.

Which markets ?

According to Bloomberg, top 3 countries at the forefront of hydrogen investment are Germany, Japan & South Korea. Back home, Australia has already declared its intention to be among the Top 3 exporters of H2 to Asian markets by 2030.



Risks

Timing: Given the majority of the current H2 demand comes from non-retail channels (such as fertiliser, ammonia etc), there is short-term possibilities around over-supply and market volatilities.

Partnerships: As most of the value in Hydroverse's proposition originates from network effects of its green H2 ecosystem & credentials-based marketplaces, onboarding various H2 producers & supply-chain participants is the key. This implies requirements for a strong B2B sales strategy

Regulatory Risk: As Australian government is already working on a Guarantee of Origin (GO) for H2 ecosystem, it's critical to work with local government agencies (such as *Department of Industry, Science, Energy and Resources*) and any consultancies (such as Energetics) engaged by the government, to navigate around regulatory frameworks intended to be imposed around H2 distribution and certification.

Go-to-market Strategy

- **Regulation**: As mentioned earlier in the regulatory risk section, working with relevant government agencies could be part of a good GTM strategy

- **Tech**: Although Holochain looks a better technology fit, it may incur increased development cost/time, given its excessive focus on providing an open framework. Much of the hApp's configuration rules (DNA) such as privacy & governance needs to be custom developed for H2 ecosystem while keeping an eye for regulatory compliance. Ditto for any pluggable supply-chain solutions. Thus, it may be worthwhile to explore the HyperLedger ecosystem given its richness, availability of various pluggable components & community, as long as throughput (TPS) requirements are somewhat lowered for a potential PILOT implementation.

- **Sales**: Hiring an experienced B2B sales team specialising in energy markets & trading should be a high priority, while focusing on specific geographies at the fore-front of H2 investments & early-adoption, appropriately supported by respective governments

References

1. A Hydrogen Guarantee of Origin scheme for Australia. Discussion Paper, GoA, 2021. https://storage.googleapis.com/converlens-au-industry/industry/p/prj1a3de348a6c0ad7d282f7/public_assets/Discussion%20paper%20-%20A%20Hydrogen%20Guarantee%20of%20Origin%20Scheme%20for%20Australia.pdf PDF file.