

Blockchain-based payment for supply chains

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- Hydrogen is a part of the Australian government's pivot towards clean energy.
 - i \$540 million pledge for “clean” hydrogen.
 - ii Global market worth USD155 billion by 2022.
- Can an emissions trading scheme (ETS) be integrated into a blockchain with hydrogen certificates?
 - 1 Or more generally, for any energy certificate?

Hydrogen Energy

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- Hydrogen is a clean fuel that produces only water when consumed.
- Harvested from sources of renewable energy: solar and wind.
- Commonly harvested through natural gas reforming and a technique referred to as *electrolysis*.

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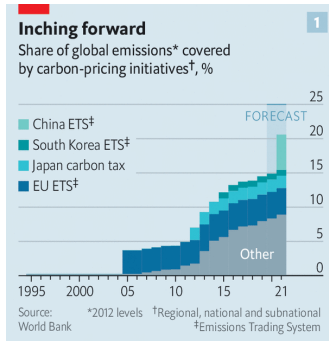
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- Is there a usable blockchain solution that will develop 'trust' in an emissions trading scheme?
- *Why?* Because customers are wary of centralised authorities with inconsistent policy (e.g. Australia).
- *How?* Using a permissioned blockchain to help develop trust without a centralised authority.

Economics of Emissions Trading

- Fix the supply S of carbon in a market. *Ceteris paribus* quantity $Q \downarrow$ and the carbon price $P \uparrow$.
- Increasing popularity: big markets are China ETS and EU ETS.
- Market price for carbon permits set through an auction.



The Economist

¹ "The World Urgently Needs To Expand Its Use Of Carbon Prices". 2020. *The Economist*.

<https://www.economist.com/briefing/2020/05/23/>

the-world-urgently-needs-to-expand-its-use-of-carbon-prices

- The use of *smart contracts* can ‘nudge’ consumers of hydrogen to use cleaner hydrogen.
 - ① A ‘carbon price’ enforced by a player in the system.
- Punishing non-clean sources of energy through smart contracts can accelerate the removal of negative externalities.
 - ① Rapidly adjust to ‘cleaner’ equilibria inside a market.
- Economic support: “If economists ruled the world, carbon prices would drive most of the action on climate change” - *The Economist*.

Hydrogen Certificates

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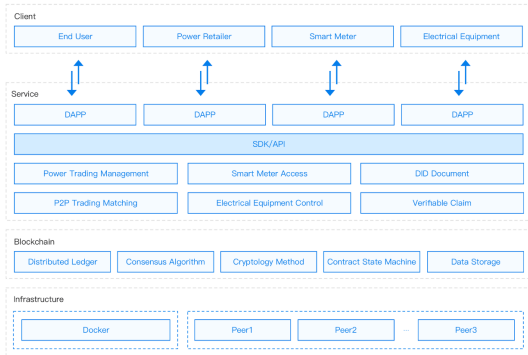
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- An approach for formally attesting the level of cleanness in a produced unit of hydrogen.
 - ① Shared across the supply chain.
 - ② Can attest to standards related to Hydrogen safety and quality.
- An agent in the blockchain can act as the certification body.
- Producers can **use** hydrogen certificates in the carbon market to spend carbon tokens.

Distributed Energy System

- *Li et al., (2019)* developed a blockchain architecture for the energy market using smart contracts with non-cooperative game theory.



¹Li, Yanan, Wentao Yang, Ping He, Chang Chen, and Xiaonan Wang. 2019. "Design And Management Of A Distributed Hybrid Energy System Through Smart Contract And Blockchain". *Applied Energy* 248: 390-405. doi:10.1016/j.apenergy.2019.04.132.

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- A European certification scheme for clean hydrogen.
- 75,000 digital certificates issued.
- Software system.
- Allows for registration, issuing and transfer of certificates.

ETS for Industry 4.0

- Khaqqi uses blockchain components to address issues with ETS management and fraud.
- Goal was to improve ETS efficiency and motivate industry participation.
- Uses a reputation system to assist with pricing.
- Used *MultiChain* to implement.

¹Khaqqi, Khamila Nurul, Janusz J. Sikorski, Kunn Hadinoto, and Markus Kraft. 2018. "Incorporating Seller/Buyer Reputation-Based System In Blockchain-Enabled Emission Trading Application". *Applied Energy* 209: 8-19. doi:10.1016/j.apenergy.2017.10.070.

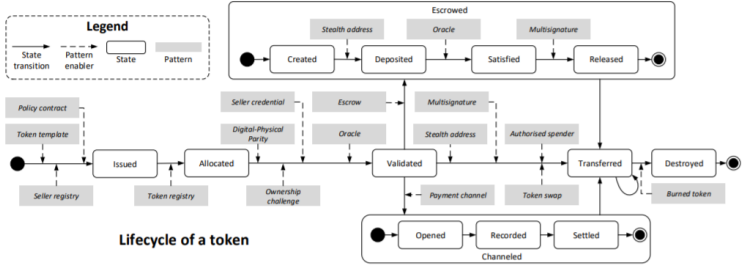
TransActiveGrid

- Blockchain and distributed generation of electricity to create a ‘point-to-point’ trading model.
- Allowed households to sell electricity between each other.
 - Reason for the failure of the platform.
- First energy market based blockchain technology in the world.

¹Pan, Yuting, Xiaosong Zhang, Yi Wang, Junhui Yan, Shuonv Zhou, Guanghua Li, and Jiexiong Bao. 2019. “Application Of Blockchain In Carbon Trading”. Energy Procedia 158: 4286-4291. doi:10.1016/j.egypro.2019.01.509.

Patterns

- Token template pattern
- Token registry pattern
- Policy contract



¹Lu, Qinghua, Xiwei Xu, Dilum Bandara, Shiping Chen, and Liming Zhu. 2021. "Design Patterns For Blockchain-Based Payment Applications". *ACM*. doi:10.1145/1122445.1122456.

Token Patterns

- Have a *Carbon Coin* to represent a permit to emit a certain amount of carbon units (a token).
- *Carbon Coin* is spent or 'burned' on using a hydrogen certificate.
 - A hydrogen certificate has a level of associated carbon.
- An authority handles the issuance of tokens to producers of carbon.
- Tokens are able to be purchased in auctions run by an authority (e.g. EU ETS).

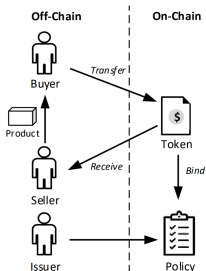
Token Derivatives

- To replicate a real emissions trading scheme like EU ETS, individuals can buy and sell derivatives of carbon tokens outside of a centralised authority.
- Financial derivatives are mappable to real tokens allowing producers to emit carbon.
- Optional trading of carbon tokens based on a 'carbon reputation' of a buyer/seller.

¹Talberg, Anita, and Kai Swoboda. 2013. "Emissions Trading Schemes Around The World". Parliament of Australia. parlinfo.aph.gov.au.

Policy Contract

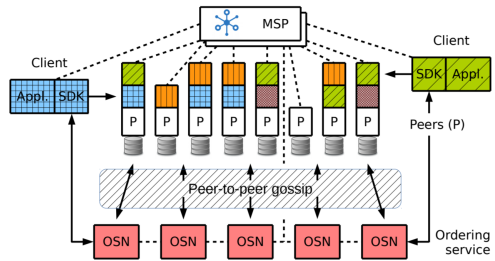
- Carbon tokens have policies to allow for spending.
- Assumption is that Hydrogen Certificates already exist in the system.
- An example policy is for carbon emissions - a certificate can be provided to spend carbon tokens.



¹Lu, Qinghua, Xiwei Xu, Dilum Bandara, Shiping Chen, and Liming Zhu. 2021. "Design Patterns For Blockchain-Based Payment Applications". *ACM*. doi:10.1145/1122445.1122456.

Fabric

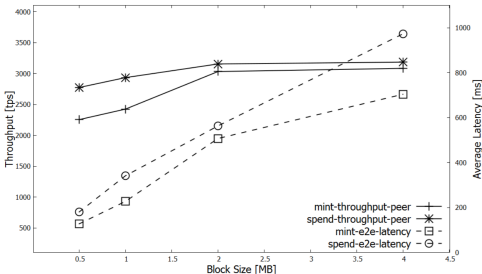
- A modular and extensible open-source system for developing blockchain applications.
- Pluggable consensus algorithms.
- *Chaincode* in general programming languages.
- Channels for enterprise confidentiality.



¹Androulaki, Eli, Artem Barger, Vita Bortnikov, Christian Cachin, et al. 2018. "Hyperledger Fabric: A Distributed Operating System For Permissioned Blockchains".

Fabric Architecture

- Novel *execute-order-validate* architecture supporting high throughput transactions.
- Dedicated ordering nodes.
- Support for up to 3560 TPS (lab environment).



¹Androulaki, Eli, Artem Barger, Vita Bortnikov, Christian Cachin, et al. 2018. "Hyperledger Fabric: A Distributed Operating System For Permissioned Blockchains".

Fabric Projects

- GoDirect Trade introducing trust into the supply chain for used aeroplane parts.
- OrgBook British Columbia helping small businesses find critical information about business partners.
- A permissioned blockchain as a 'trust machine' for organisations.

¹ "Orgbook Case Study – Hyperledger". 2021. *Hyperledger*.
<https://www.hyperledger.org/learn/publications/orgbook-case-study>.

² "Case Study: Honeywell Aerospace Creates Online Parts Marketplace With Hyperledger Fabric". 2021. *Blog. Case Studies*. Accessed April 14.

- The government can use the blockchain to deliver trust and growth in emissions trading.
- Smart contracts can be applied for the buying/recording of emissions in a carbon market for producers.
- Previous blockchain energy solutions rely on centralised parties or use the blockchain to act as an 'auction house'.
- Prior attempts disrespect user freedom by assigning a reputation to actors in a carbon market.
- Blockchain has seen recent leaps with high throughput transactions making the technology for a blockchain carbon market feasible.

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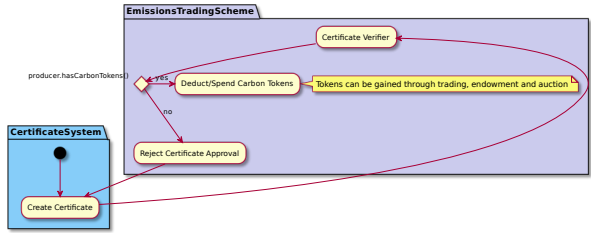
- 1 Establish requirements for actors in the system.
- 2 Formalise authorities in the Hydrogen market as nodes in Fabric.
- 3 Express business logic for actors as 'chaincode'.
- 4 Develop a user interface for actors to interact with the blockchain.

Architecture Details

- Crash Fault Tolerant consensus algorithm: *Raft*.
 - Ensures high throughput transactions.
- Utilise Fabric channels to keep pricing information related to Hydrogen suppliers confidential.
- API endpoints to interface with the blockchain.
- Web application for users to query and modify the blockchain.

Certificate Interaction

- An ETS system validates hydrogen certificates with carbon tokens.
- Trading hydrogen certificates requires approval from ETS.



Solidity Example

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```
1  pragma solidity >=0.8.3;
2
3  contract Certificate {
4      function purity() constant returns (uint256) {
5          return ...;
6      }
7  }
8  contract ETSPProvider {
9      function burnCarbon(Certificate certificate)
10         constant returns (uint256) {
11         return ...;
12     }
13     function placeBid() constant returns (bool) {
14         return ...;
15     }
16 }
```


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- ① Problem has been defined.
- ② Deep-dive on Hyperledger.
- ③ Learning about smart contracts and Fabric's novel approach using 'chaincode'.
- ④ Literature review on previous blockchain solutions creating an ETS and energy supply chains employing Hyperledger.

Research Timeline

