School of Computer Science and Engineering

Faculty of Engineering

The University of New South Wales

Blockchain-based Carbon Market

by

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Thesis submitted as a requirement for the degree of

Bachelor of Science in Computer Science and Engineering (Honours)

Submitted: April 2021

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Topic ID: Blockchain-based Payment

Abstract

Emissions trading schemes (ETS) are a policy tool at the forefront of the fight against climate change. In this thesis, I will present a blockchain-based approach for creating a carbon market driven by hydrogen certificates. By using carbon tokens, an effective price can be placed on the use of carbon removing a market failure existing in the production of natural resources. I will use a high-throughput permissioned blockchain to motivate how trust can be placed in a market made volatile by inconsistent government policy and scepticism on the behalf of participants.

Abbreviations

BTC Bitcoin

USD United States Dollar

EU European Union

ETS Emissions Trading Scheme

TPS Transactions Per Second

Contents

List of Figures

List of Tables

Chapter 1

Introduction

A blockchain can be defined as an immutable ledger maintained by a network of mutually untrusting peers [ea18a]. Since the creation of Bitcoin (BTC) in January 2009 by the maverick Satoshi Nakamoto there has been an explosion of interest in the underlying technology behind blockchains. Specifically, the immutability and openness of the distributed ledger makes blockchain an attractive option for markets with untrusting participants exposed to information asymmetry. The market for carbon is particularly well suited to the blockchain due to inconsistent government policy - for example the ill-fated outcome of the Carbon Pollution Reduction Scheme in Australia [ea13].

Recent attempts to create blockchain-based carbon markets have been met with some success - but have been held back by technicalities or innovations that disrupt the fundamental goal of using the blockchain as a 'trust machine' [The15]. I will outline how hydrogen certificates on the blockchain can be used to automatically spend carbon tokens and add extra validation before being sold on the commodity market. Hydrogen is particularly well-suited as an example for certificate-based carbon markets due to hydrogen producers attaching a carbon footprint to certificates.

I shall summarise how permissioned blockchains are principally useful for carbon markets due to support for high-throughput transactions. A carbon market would have to scale to a large number of distributed producers with scalability matching hydrogen energy production - an industry expected to be worth USD155 billion by 2022 [ea18b]. I will propose Hyperledger Fabric as a blockchain framework - chiefly due to its support for up to 3500 transactions per second (TPS) and a plugable consensus algorithm [ea18a]. Moreover, my proposed solution will accommodate an optional carbon 'reputation' as part of the price for exchanging carbon tokens between producers.

In Chapter 1 an overview of the thesis and its novel approach to certificate-based carbon markets is presented. In Chapter 2 I outline the background to the project and important literature for markets on a blockchain. In Chapter 3 I provide methodology for the blockchain architecture. In Chapter 4 I outline some preliminary results with creating smart contracts (programs on the blockchain) for auctions on a public blockchain. In Chapter 5 I conclude with some remarks on the future potential for the thesis topic.

Chapter 2

Literature Review

2.1 Brief Background

The pricing of carbon emissions is a policy tool where emitters must pay for carbon usage - thereby disincentivising reliance of unclean source of energy. The conventional wisdom held by economists is a price on carbon will provide an incentive for emitters to be 'priced' out of using unclean energy and choose to invest in clean renewable energy like solar and wind. The economic theory behind carbon pricing is simple - according to neoclassical economics markets are prone to failure due to free riding. In the case of carbon, emitters free ride by releasing carbon without considering the cost of carbon to the planet and society. To remove the deadweight loss due to free riders, economists propose placing a price on carbon to properly adjust emitting markets to a socially optimal equilibrium price.

Presently, the great majority of humankind's emissions are not placed under a price, with only 20% of global emissions under a pricing scheme [The20]. Globally, the largest emissions trading schemes (ETS) are run by the European Union (EU) and China. The EU ETS has recently been expanded to cover around half of all emissions produced inside the EU (see Figure 2.1). Notable economists suggest that for a carbon price to be effective in fulfilling the Paris pledge then prices must stay between the range of

\$40-80 per tonne [The20]. As of 2020, the existing median price per tonne of carbon emissions is only \$15 [The20].

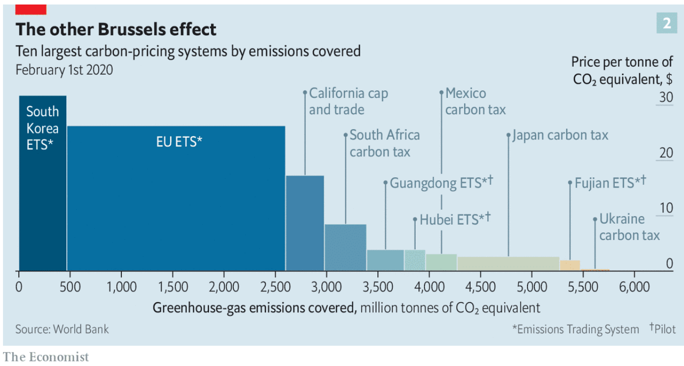

Figure 2.1: Largest Emissions Trading Schemes

Carbon prices are open to government manipulation from centralised authorities and are often the subject of heated debates. An example was the 'axe the tax' campaign resulted in the abolishment of the Australian ETS in 2014 [The20]. Moreoever, there is often debate over where the money associated with carbon prices will go - particularly in the case where an auction for carbon credits occurs. If money raised from an ETS is used to lower taxes elsewhere then opponents on the left of politics accuse the policy of not actively fighting climate change. Generally, opponents on the right accuse carbon prices of stifling economic growth - an example of an unecessary government overreach.

The blockchain, which acts as an immutable ledger, has the potential to deliver 'trust' into the market for carbon. As opposed to being run by a centralised authority like the government, it can instead be run openly on the blockchain visible to all participants in the market for carbon. Therefore, the openness of a blockchain ETS can be used to combat its most fierce criticsm - which is its usage as a political tool. A blockchain ETS can be designed so a 'fee-and-dividend' is used, meaning the distribution of payments can go straight back to the people thereby incentivising long-term adoption [The20].

I will use the rapidly growing Hydrogen energy market - with its novel Hydrogen certification process - to show how producers can pay for accrued negative externalities. Hydrogen certificates can be automatically submitted with a level of recorded emissions, whereby tokens are deducted from a producer's carbon account upon submission. Smart contracts (programs on the blockchain) will be used to represent the logic of an ETS targetting hydrogen energy producers.

2.2 Hydrogen Certificates

The hydrogen market is a growing form of energy production created from resources such as natural gas, coal, solar and wind. Hydrogen is deemed a 'clean fuel' because when it is consumed in a fuel cell only water is produced. The hydrogen market is particularly important for Australia since the industry is expected to create up to 7,600 jobs and contribute $11 billion a year to GDP [COA19]. As part of an effort to reduce cumbersome regulation associated with Hydrogen markets internationl standards have been developed. Moreoever, standards embedded into a *hydrogen certificate* can assist to manage the lifecycle of hydrodgen and ensure carbon is not being emitted. As of 2020, there are eight international hydrogen standards (see Table 2.1) defining features such as safety and quality [Sta20].

Standard	**Description**
AS 16110.1:2020	Safety
AS ISO 16110.2:2020	Performance
AS ISO 14687:2020	Fuel Quality
AS 22734:2020	Industrial, commercial, and residential applications
SA TS 19883:2020	Safety of pressure swing adsorption systems
AS ISO 16111:2020	Transportation
AS ISO 19881:2020	Gaseous hydrogen
AS 19880.3:2020	Gaseous hydrogen – Fuelling stations

Table 2.1: International Hydrogen Standards

To help develop standards, centralised certification authorities are being developed to act as certification schemes for hydrogen. One of the most popular such schemes is CertifHy - a European scheme for hydrogen certification [cer21]. Centralised certification schemes provide services such as the issuance of hydrogen certificates along with the ability for users to create an account to track the registry of owned certificates.

Generally, hydrogen certificates have the ability to detail technical information along with crucial greenhouse gas information.

A key problem with the centralisation of certification authorities is the lack of openness involved. Customers become reliant on a key provider to conduct certification, fostering less 'trust' in the market for hydrogen. Due to a lack of trust, a blockchain-based approach to hydrogen certification would allow for greater extensibility in the different certificates available. Crucially, an ETS with on-chain energy certification can enforce carbon prices in a market. For example, if a hydrogen certificate has not paid for its carbon usage using the on-chain ETS - then due to the immutability and openness of the blockchain such a certificate could be marked as not valid for trading inside a commodity-market. This thesis will make the assumption that such a rigorous certification scheme exists, and will outline how an ETS can be constructed to make use of certificates created by producers thereby pricing carbon.

2.3 Blockchain Emission Trading Schemes

2.3.1 Bitcoin-based ETS

An early adoption of blockchain carbon pricing was the creation of a bitcoin-based emissions trading infrastructure model in 2015 [AS15]. The model proposed a blockchain called Decentralised Carbon Emissions Trading Infrastructure (D-CETI) inheriting a significant amount of the innovations created with Bitcoin by Satoshi Nakamoto in 2009. The authors proposed that the significant barriers limiting the effectiveness of the major ETS schemes (EU ETS) was the lack of security and privacy participants face in cardbon trading [AS15]. As a solution, Bitcoin's at the time novel approach to security using hashed transactions and computationally difficult hash puzzles was deemed by the authors as an appropriate solution to the shortcomings of the large ETS schemes.

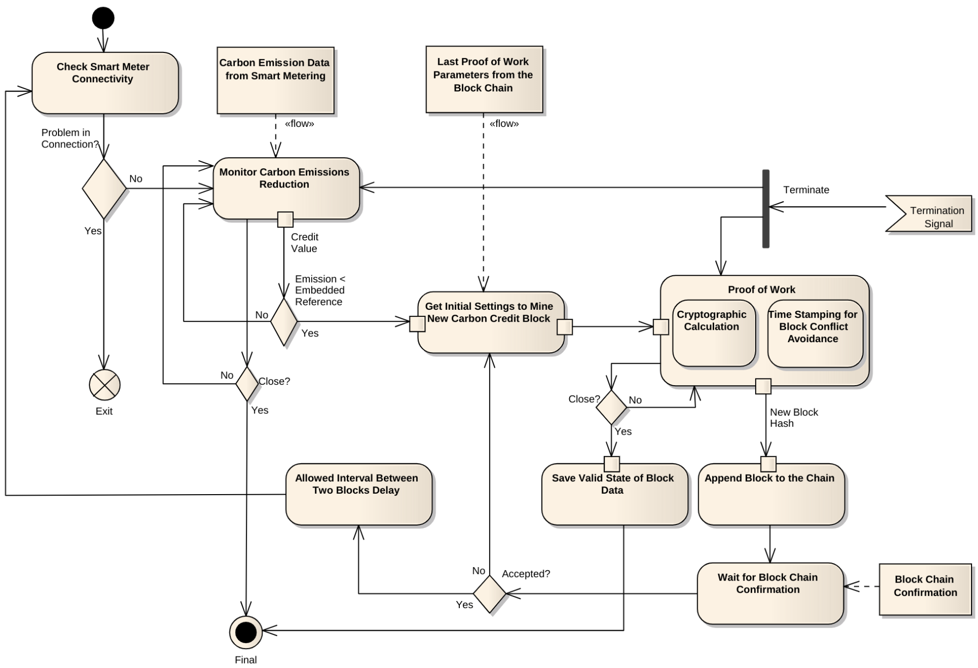

Figure 2.2: Bitcoin-based ETS

In principal, the bitcoin-based ETS proposed functionality for users to generate carbon tokens, register, sell, and bid for credits. As a result, the system for a carbon market was almost identical to the cryptocurrency Bitcoin with the primary difference being the use of an ETS focused coin. To deal with the throughput demands for an active ETS market, the block generation rate on the chain became one block every 150 seconds in contrast to Bitcoin's one block every 600 seconds [AS15]. Moreoever, participants in the bitcoin ETS market would have to generate new blocks through miners solving cryptographic hash puzzles (see Figure 2.2).

The downsides to the bitcoin-based ETS are significant - the throughput of the system is too low to ever be usable in an active ETS market. Although increasing the throughput from 7 transactions per second (TPS) for Bitcoin to roughly 28 TPS, such a solution still relies on computationally expensive mining to achieve system consensus [AS15]. Moreoever, Bitcoin's reliance on hash puzzles requires the continuous consumption of carbon emitting energy - potentially worsening the market failure which the ETS is aiming to remedy.

The bictoin-based ETS relies on a primitive form of smart contracts inherited from *Bitcoin Script* - meaning the smart contracts are not turing complete. Therefore, it would not be possible to express detailed business logic such as the auctioning of tokens or custom carbon prices into such an architecture. Simply stated - a Bitcoin-based ETS is insufficient for a carbon market.

2.3.2 Blockchain-based Smart Grid

A more innovative public blockchain, such as Ethereum, has been proposed as a system to host local energy markets [ea17]. The benefit of using Ehtereum primarily comes from the use of a turing-complete Ethereum Virtual Machine allowing for the creation of complex smart contracts. Hence, the creation of an intricate local energy market becomes possible through a distributed programs written in a high level language (such as Solidity) which is then compiled into Etherum bytecode. The researchers found the use of Ethereum as a local energy market allowed for electricy cost reductions across a model scenario [ea17].

Despite the technical feasibility of developing an ETS on Ethereum, the platform is not suitable due to technical limitations. The researchers acknowledged that further analysis into the suitability of public blockchains for energy markets is required [ea17]. Specifically, Ethereum supports a 25 TPS for system throughput [Rac21]. For an active ETS in an emerging industry such as hydrogen production, such a low system throughput would do damage to the usability and customer satisfaction involved in carbon trading. Moreover, Ethereum is being actively developed and has planned forks due to a move towards a proof of stake consensus algorithm [Ozo21] - making it unstable for a certificate-based ETS requiring customer trust.

2.3.3 Reputation-based ETS Blockhain

Researchers in 2017 proposed the use of a reputation-based ETS with a blockchain infrastructure, employing a permissioned blockchain to overcome the throughput issues asscoiated with public blockchain networks [KSHK18]. The researchers concluded that the environment *Multichain* would be a good candidate for a blockchain ETS due to its support for a system throughput with up to 1000 theoretical TPS [KSHK18]. Similar to previous blockchain carbon markets, the researchers made smart meters and the trading of tokens central components to the functioning of the system - as observed in Figure 2.3.

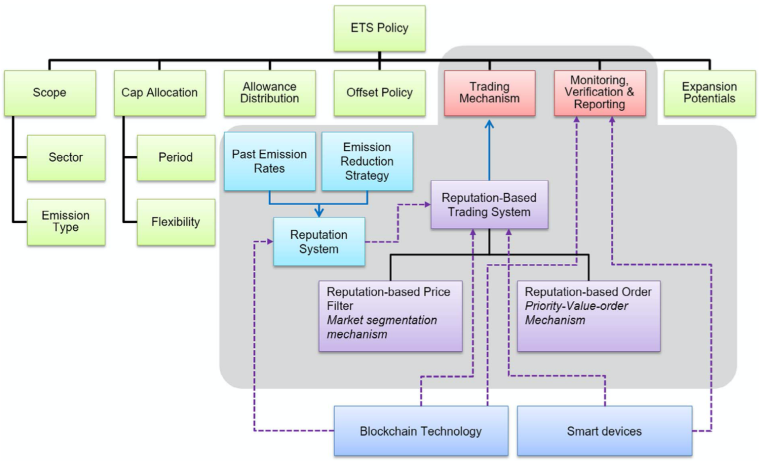

Figure 2.3: Reputation-based Blockchain ETS

Khaqqi et al believed that the critical element holding back the success of a blockchain ETS is the lack of a reputation model present in the pricing of carbon tokens. Often, markets can increase in quality and therefore grow when there is a way to remove systemic information asymmetry [KSHK18] (as an example consider online marketplaces and seller scores). Therefore, Khaqqi et al proposed the incorporation of the 'carbon reputation' of a seller into the pricing of carbon tokens. As observerd in Equation 2.1, changing the 'reputation' parameter to factor a seller's carbon emissions can influence the price offered to agents buying tokens in the ETS blockchain [KSHK18].

$$\mathrm{PV} = \frac{\mathrm{askingprice}}{\mathrm{reputation} - \mathrm{basedfactor}} \tag{2.1}$$

Despite offering a solution with significantly more system throughput than both Ethereum and Bitcoin-based offerings there has not been a general movement towards an ETS with reputation pricing. A weakness of the architecture employed by Khaqqi et al is the requirement that prices must automatically reflect the 'carbon reputation' of sellers in the marketplace. Forcing reputation systems upon users is disrespecting of user freedom, and should be made an option and not a requirement for participating in the system. Moreover, as The Economist stated - public criticism and politics are key factors holding back the success of a carbon market [The20]. Hence, a system driven by on-chain energy certificates would make a blockchain ETS more usable driving long-term adoption of a carbon market. Moreover, to garner public support a dividend payout from the system to the public/end customers would help in getting necessary political support [The20].

Chapter 3

Project Plan

Chapter 4

Project Dependent Preparations

Chapter 5

Conclusion

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Appendix 1

Appendix 2