KEY DETERMINANTS OF ACHIEVING TRUST IN APPLYING BLOCKCHAIN TO EMISSION TRADING IN FINLAND

by

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A thesis submitted in partial fulfilment of the
requirements for the degree of

MSc. Information Technology for Enterprise
Management (double degree)

Tilburg University & University of Turku

2022

Supervised by dr. Joris Hulstijn

Date 30-07-2022

ABSTRACT

A thesis presented on the critical moment of sustainability transition especially regarding reducing emission of carbon dioxide. The disruption of blockchain application has become one of the innovations that can facilitate this transition. This thesis research focuses on the investigating the most influential trust determinants of applying blockchain to emission trading system (ETS) in the context of Finland. This is exploratory qualitative research which combines grounded theory applied for eight empirical papers and three semi-structured expert interviews. The interviewees include two Finnish ETS experts and two blockchain application experts. Through the qualitative analysis, the author suggested structural assurance trust, knowledge-based familiarity trust and control-based trust to be the most deterministic trust factors in applying blockchain to emission trading. Meanwhile, situational normality trust, peer-based trust and ethnical trust can also be influential. A sequential model and a pyramid model of different trust factors mentioned have been proposed based on the interpretative findings of interviews. Therewith, a consolidated trust model was suggested involving all the relevant trust factors. Finally, the research results can be highly generalisable towards member countries of EU ETS other than Finland.

PREFACE

I am deeply indebted to dr. Joris Hulstijn, who guided me through this master thesis journey from start till end. I would also thank Prof. Hannu Salmela and dr. Emiel Caron who gave me advice on my research proposal. Meanwhile, I sincerely appreciate the blockchain expert from Gold Standard, the blockchain expert from NRGCoin and the ETS experts from Finnish Energy Authority (Energiavirasto) for participating in my semi-structured interviews. With any of your help lacking, I would not be able to accomplish this exploratory qualitative research before the deadline.

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INTRODUCTION

Last years saw blockchain evolved into institutional-change technology in all different businesses sectors over the world (Swan, 2015; Williams et al., 2016). Amongst other disruptive technologies with industrial and institutional impact, blockchain has been considered as a key innovation driving power (Karamchandani et al., 2020). The technology facilitates exchange of value over Internet without requisite of third-party verification companies, but in a most secure manner. It was estimated the market size for blockchain applications should reach $7.59 billion by 2024, demonstrating a sizable growth that resonates with the call of demand among different industries (Grand View Research, 2019).

Recent research has attributed increased amount of blockchain applications and even more prominent prospect to the trusts built up between end-users and stakeholders in business networks (Kshetri, 2018; Meijer & Ubacht, 2018). Unlike traditional contractual trust that relies on endorsement of verification institutions, blockchain is trusted by different parties of business transaction because they find the processes of blockchain application trustworthy. They have confidence in blockchain mechanism which provides them with transparency, accuracy and unforgeability (Christidis & Devetsikiotis, 2016). Thence trusts are established due to the confidence in technology and algorithm instead of institutional authority (Shin, 2020b; Vermaas et al., 2010).

1.1 CLIMATE CHANGE AND ETS

Nevertheless, should an emerging technology like blockchain be widely accepted and adopted, it must be relevant to the advancement of human society, even better if it could enhance the efficiency of societal advancement. Although our society can be advanced in different dimensions, enhancing sustainability of our living Earth may be the most imminent for the coming decades. Since industrial revolution commenced in 1760, last three centuries have seen anthropogenic activities generating colossal outlet of GHG, particularly due to the excessive usage of fossil fuel for energy generation and transport (Mgbemene et al., 2016). The predominate contributors to GHG are CO2, Methane (CH4), Nitrous Oxide (N2O), and Fluorinated Gases (F-gases). In 2017, the worldwide major gases emissions constituted of 72% CO2, 19% CH4, 6% N2O, and 3% F-gases. Obviously, carbon dioxide is the largest component of GHG, whose major suppliers were coal combustion (39%), oil combustion (31%), natural gas combustion (18%), and cement production (4%) (Olivier et al., 2017).

Global warming is a major consequence of persistent GHG emission. In 2010, World Bank has drawn a conclusion that 2℃-warmer global temperature has brought vital repercussions: 1) substantial ice loss and sea-level rise, 2) extreme weather conditions with more frequent floods, draught and forest fire, 3) increased spread of deadly disease, 4) extinction of more than a quarter of animal species, 5) substantial decrease of food supply, among countless other damages (Mgbemene et al., 2016). Unruh (2000) asserted that in all countries undergone industrialisation, the predominate reason of climate change is confirmed as satisfying consumers' needs for products and service via application of carbon-based energy sources. More specifically, statistics disclosed the top-six producers of GHG are China, United States, European Union, India, the Russian Federation, and Japan (Olivier & Peters, 2020).

Such severe extent of climate change impact decides that any great institutional technology should be contributory towards sustainability especially abatement of GHG emission till the near future. Thence despite the advantages of blockchain technology, it may not be highly respected among human society until its applications can enable CO_2 reduction.

Regardless of adopting blockchain technology or not, the genetic instinct of business entities is prioritising profits from taking social responsibilities. Therefore, establishing mandatory regulations with punishments is, in most sectors, essential to ensure CO_2 producers to actually obey carbon reduction policies. Issuing emission permits, together with imposing taxes, has proven an effective approach to restrain gas emission (ICAP & World Bank, 2021; Spulber, 1985). As an approach concordant with permit issuance, cap and trade or emission trading has historically been successful to incentivize enterprises and nations restricting their pollution emission (Chestnut & Mills, 2005).

Carbon dioxide emission trading system was initiated by the Kyoto Protocol, an international treaty aiming to curtail greenhouse effect and urge all countries in the world to issue national policies for continuous carbon emission reduction in all industries (Caryl-Sue & Crooks, 2021). This international agreement came effective in February 2005 and was officially concurred by 192 state parties (United Nations, 1997). Generic procedures of emission allowance allocation and trading are similar across the globe because all state parties of the Protocol committed to the same objective. But ETSs can vary between countries or even between regions of the same country, contingent to their own legislation processes and carbon emission situations. Also, CO_2 ETSs should not be concrete bricks, they should be adjustable according to the project reviews and expert consultation over time, hence the ETSs should always be at a development stage (ICAP & World Bank, 2021).

1.2 ETS CONTINUITY

Consistent with the proposal of developing emission trading system, the European Union, as a major party of Kyoto Protocol, pioneered their version of emission trading scheme (EU ETS) in 2005, which entered its fourth Phase in 2021 (ICAP & World Bank, 2021). Gaining both praise and blame from trial period Phase 1 and official implementation period Phase 2, the EU ETS encountered a major setback especially mixed with aftermath of 2008 economic crisis during Phase 2. The emission allowances in EU carbon market depreciated below a level that could neither punish the excessive carbon emitters nor incentivise the concerned sectors to invest in more sustainable energy sources (European Parliament, 2017; ICAP & World Bank, 2021). Confronting with the waterloo, EU ETS suspended 900 million allowances being auctioned during 2014-2016 but allowed them to be traded again in 2019-2020, naming the tactic as backloading (ICAP & World Bank, 2021). The aim was to stop the deflation of emission allowances and prepare for a more stabilised solution which would come soon.

Not only did EU ETS encounter waterloo, but the Kyoto Protocol had not fulfilled its expected efficacy either. Due to the lack of general awareness, clear targets and harmonised obligations over the globe, the GHG-reduction success of the Protocol has been restricted. Hence United Nations scripted the Paris Climate Change Agreement (commonly as Paris Agreement), as an enhancement to substitute the Kyoto Protocol, and made it effective in 2016. The target of Kyoto Protocol, was to stabilise GHG emission and stop human interference to climate system (United Nations, 1997), whereas the objective of Paris Agreement is written as maintaining increase of temperature to below 2°C above pre-industrial levels and pursuing for 1.5°C above pre-industrialisation; achieving net-zero carbon emission around mid-21st century (United Nations, 2015). The Agreement has been signed by 195 countries and endorsed by 190 till January 2021 (ICAP & World Bank, 2021). CO_2 ETS is embedded in Paris Agreement since drafting, but it emphasises on more renegotiation amongst all countries and reformation of an internationally harmonised ETS (ICAP & World Bank, 2021).

As a major supporter of Paris Agreement, EU vowed to proceed with its emission trading system with a notion of realising carbon neutrality in 2050. In 2018 the Union reiterated that EU ETS would be proceeded with more governmental and systematic interference against extreme market volatility (European Parliament, 2017). In practice, the suspended allowances were resumed auctioned in 2019 (late Phase 3) with the introduction of Market Stability

Reserve, which was designed for a more sustainably stable allowance market entering Phase 4.

Finland, as one of the 27 member states of EU, has traditionally been a forerunner of sustainability (Näyhä, 2019), and in respect to CO_2 abatement, they have decided not to make an exception. The Nordic country has full compliance with EU ETS from Phase 1 in 2005 plus making a commitment of achieving carbon net-zero before 2035, a 15-year advance from EU's objective (Finnish Government, 2019). Despite historic frustrations along first two Phases with the whole EU ETS development, Finland has restated their continuity with emission trading approach and ratified the Paris Agreement in November 2016 (Ministry for Foreign Affairs of Finland, 2022). Following the Union's new commitment of accomplishing 55% carbon reduction by 2035, the country has proactively constructed a roadmap for national ETS to include transport and building industries, which will be ready to take off before 2026, should the advancement of EU ETS derail during next few years (ICAP, 2022).

1.3 ETS AND BLOCKCHAIN

It is a question whether blockchain technology can be the technological solution that facilitates or ameliorates ETSs thus prove its institutional significance in societal development. Analysed the current ETS, Al Sadawi et al. (2021) argued that the solid transparency property of blockchain technology could enhance ETS' monitoring and tracking actual emissions as well as trading allowances through averting double counting issue. The type of manipulation committed by ČEZ group may be prevented (see also Section 2.2-Challenges of ETS), had the major actors' carbon-trading-related conduct been transparently verified by the peers and market administrator, for instance, via blockchain application (Skene & Murray, 2017).

Moreover, blockchain application may be the ideal solution to provide a platform where participants of a carbon market can conduct peer-to-peer trading with security, authenticity and privacy regarding data storage and allowance transferring (Al Sadawi et al., 2021). UN-certified sustainability expert Andrei Marcu stated in Pigeolet and Van Waeyenberge (2019) that there should be one proper carbon market where participants share their abatement results, coordinate and collaborate with each other smoothly along trading processes. Blockchain technology appears to be a perfect answer to the request of Mr Marcu that assists in developing a common ETS amongst all major CO_2 producers and avert integrity and consistency issues depicted above (Al Sadawi et al., 2021). Same as what Climate Chain Coalition argues: adopting blockchain may increase capital market confidence and assist in accomplishing objectives of alleviating climate change at both regional and universal scales via its consensus mechanisms and interoperability (Pigeolet & Van Waeyenberge, 2019).

Inevitably, applying any emerging technology to actual business model always takes considerable amount of time to mature, because empirical experiences and scientific analyses on those experiences at different business domains simply consumes time and resources. Also, blockchain itself demands continuous technological upgrade to be more cost-efficient so as to outstand itself amongst other technology alternatives. Fu et al. (2018) considered blockchain application to enhance sustainability is presently still at a primary stage. But once sufficient experiments conducted and technological knowledge obtained, plus firm momentum given by the ETS regulators, Richardson and Xu (2020) believed “critical mass” will be reached thus an ideal blockchain solution will emerge. The solution may then become a significant success factor for a mature regulatory market. In fact, Article 6 of 2018 Paris Agreement has formed a basis for decentralised collective sustainability actions. Blockchain is considered a key technology of attaining climate targets through participating in the future ETS (Asian Development Bank, 2018; Dinakaran et al., 2019).

Besides Paris Agreement, other governmental exploration of blockchain application for carbon dioxide emission trading include: Chinese Government’s collaboration with IBM Hyperledger to track CO_2 emission in 2013 (IBM Corporation, 2018); Chilean Government’s adoption of Ethereum to trace energy consumption and carbon emission since 2018 (Jones, 2021); German and Mexican Ministries’ insightful joint-investigation of applying blockchain for ETS in 2019 (Braden, 2019b). In mid-2022, European Commission officially released 7 steps of strengthening blockchain adoption in Europe to achieve climate goals more efficiently (European Commission, 2022a).

On a universal level, in 2018 UN depicted blockchain’s efficacy and potential role on an administrator report of Kyoto Protocol implementation (United Nations, 2018). One year earlier, during One Planet Summit on the second anniversary of Paris Agreement, a multi-stakeholder group of 25 organisations founded a global initiative named the Climate Chain Coalition (CCC), as a major member of which, UN has committed to collaborate and support blockchain application for serving climate change objectives (UN Climate Change News, 2018). All these relentless efforts among other countless cases have underpinned a potential regulatory impetus for blockchain application to reach the “critical mass” and make qualitative change on ETS in the near future.

1.4 CHALLENGES OF APPLYING BLOCKCHAIN TO ETS

In spite of the unique advantages of blockchain, governmental awareness and global incentives, blockchain has not been substantively trusted and applied towards emission trading for factual reasons. German and Mexican National Environment Ministries highlighted five key challenges of blockchain networks that impede adoption of blockchain approach (Braden, 2019b). Four out of the five challenges are concerned by this paper as below.

The first challenge is large energy consumption, which is a famous problem of blockchain technology. Especially when investigating its potential of ameliorating climate change, large energy consumption means large amount of GHG emission, thus contradictory towards the purpose. This issue is originated from the first and most popularly adopted blockchain consensus mechanism Proof of Work (PoW), which is utilised by the two biggest blockchain platforms of the world Bitcoin and Ethereum. Within this mechanism, participants need to consume great amount of computer energy to resolve the cryptographic puzzle in order to find a correct hash value and get rewarded with the next block of the chain. Fortunately, other mechanism alternatives have been invented, almost all with less computer energy consumption required. For instance, the second biggest mechanism Proof-of Stake (PoS), soon be adopted by Ethereum (Fairley, 2018), consumes only a fraction of energy compared to PoW, because there is no need for excessive energy to find the correct hashes. There are pros and cons with each mechanism, and some blockchain platforms are adopting two mechanisms for higher efficiency with lower energy consumption (see also Section 2.1). Hence the negativity of this particular challenge is decreasing every day along the development of the technology (Braden, 2019b).

The second challenge raised by the Ministries is scalability, which means the maximum amount of users or transactions a blockchain is able to accommodate while maintaining its mechanism operates efficiently (Braden, 2019b). Bitcoin blockchain size is restricted to 1MB for now and each block is mined about 10 mins. As a result, the efficiency of Bitcoin is 7 transactions per second, which makes a fantasy to handle millions of transactions synchronously (Zheng et al., 2018). Although Ethereum has a higher performance capability with max. 20 transactions per second (TPS) heretofore, for permissionless blockchain platforms with PoW, it is an obstacle to scale up. Again luckily, other permissioned platforms may have much higher scalability, for instance, Hyperledger Fabric with 100,000 TPS (Braden, 2019b), Solana with 65,000 TPS (Yakovenko, 2018), meanwhile they have different consensus protocols than PoW, amongst countless number of other platforms (see also Section 2.1).

In fact, Braden (2019b) argued that energy consumption and scalability, as inherent concerns of blockchain, can only be serious problems when blockchain functions with complete decentralisation. Whereas if ETS would retain certain level of central governance feature, meaning to adopt permissioned blockchain with suitable protocol, these two issues should become less significant.

The third challenge concerned the Environment Ministries was the lack of maturity and proven success. They argued most blockchain application providers lack overall marketing strategy of convincing stakeholders of ETS to trust the benefits of decentralisation and other advantages, especially compared to the well-established financial institutions (Braden, 2019b). While it is rather inevitable because the technology is indeed still "in its infancy", as Bitcoin was invented just over a decade ago and blockchain application milestone Ethereum was released in 2015. It is logical that blockchain has not had substantial track records. Moreover, as described above in this paper, official history of carbon dioxide ETS is only three years longer than blockchain, thus also craving more qualitative investigation. Therefore, research on combining blockchain and ETS like this study can contribute towards the maturity of both sides.

The fourth challenge listed by the two Ministries was the risk of "rubbish in, rubbish out", indicating that blockchain technology itself is neither a natural instrument of increasing data accuracy nor a tool of preventing fraudulent information entry. Technically, as long as data entry follows the consensus mechanism, it can be proved by the nodes to be a new block (Braden, 2019b). The measurement, reporting and verification (MRV) procedures of ETS proposed by the World Bank are complicated and EU ETS is committed to conduct MRV processes rigidly especially after the prior frustrations illustrated above (ICAP & World Bank, 2021). That implies moving from central registry to an actual decentralised approach will demand considerable resources to construct an alternative MRV system.

A positive aspect regarding this challenge is that it has been aware rather early and investigated in numerous contexts. The most popular solution proposed has been adopting IoT to provide synchronised emission data a trusted and automated MRV system within blockchain application (Dong et al., 2018; Fuessler et al., 2018). Because IoT is envisaged to construct trustable MRV efficiently with accessible audited code (Richardson & Xu, 2020). A successful example can be the Chilean government and World Bank's blockchain emission tracing pilot, where IoT monitoring stations were installed on the roofs of 10 carbon emitting facilities. The synchronised data was acquired into data loggers of the PhiNet blockchain and info blocks were created before uploading onto public dashboard (World Bank, 2020).

To confirm this example, Fu et al. (2018) proposed a blockchain framework for ETS focusing on clothing manufacture sector, which is supported by smart device for obtaining emission data. These Chinse researchers then performed a case study and proved the combination can contribute towards a more efficient and accurate ETS. Additionally, Khaqqi et al. (2018) proposed a comprehensive blockchain application model with reputation-based system for ETS, in which smart device acts as an accurate emission capturer. The researchers performed a profound case study on this model and their analysis demonstrated blockchain-enable ETS can higher the stringency of MRV thus averting non-compliant behaviour more rigidly through sharply avoiding double counting issue, compared to conventional ETS (see also Section 2.3). Richardson and Xu (2020) paralleled with this finding by stating real-time sensing will foster a compliance cycle process in EU ETS (Braden, 2019a; Fuessler et al., 2018) as well as increase emission trading activity due to "more frequent reporting and compliance".

It is logical to lose trust when a technology casts numerous doubts to be implemented. But by being able to give justified responses to the key doubts, blockchain should deserve more trust in regard to applying it on emission trading. Concerning the inherent lack of trust, Richardson and Xu (2020) raised another reason from a governance perspective. The designed procedures of current ETS all involve central authorities by default, from allowance allocation, opening trading account to carbon credits verification (Braden, 2019a) (see also Section 2.2). Although participants of the initial permissioned blockchain ETS need to trust the designated authority in order to build up the novel system as well as ensure the integrity of the issued tokens, there has not been an authority trusted equally by all market participants yet. To resolve this issue, the researchers considered "on-chain governance" will be a must, which implicates a set of rigorous regulations embedded in smart contracts of the blockchain application. They also emphasised these regulations should be defined with collaboration with representatives of various trading stakeholders at least the initial stage (Dong et al., 2018). Additionally, in the case that there will be more than one authorised token issuers, there can be misalignments between the tokens' fungibility leading to a risk of market fragmentation. In order to solve this issue, process of standardisation needs to be introduced to the blockchain application (Deshpande et al., 2017).

1.5 PROBLEM STATEMENT

As referred above, blockchain application, albeit challenges from various perspectives, it should still be a pragmatic a solution of enhancing ETS so as for more efficient alleviation of carbon dioxide emission over the globe in a near future. Moreover, the success of business transactions such as CO_2 emission allowance trading is based on trust between buyers, sellers, and verifiers. Correspondingly, the notion of blockchain is indeed to strengthen this trust with increased transparency, security, unforgeability as well as higher efficiency via decentralisation. The reasons of why the technology is yet to be generally trusted are complicated as elucidated. Trust, as psychological feeling between persons, is subjective and sophisticated. Even though blockchain seems to provide sensible paths of resolving all the demonstrated challenges, there may still be a long distance before blockchain application will be highly and popularly adopted for ETS.

Much as trust being cornerstones for both blockchain and emission trading, how users or stakeholders can achieve multilateral trust in context of applying blockchain to carbon dioxide emission trading system in Finland or even amongst European Union, is a subject of considerable discussion. This is also the problem this study focuses on and the knowledge gap we intent to fill in via exploratory research. Subsequently, the research question of this research is: *what are the decisive factors of realising trust while applying blockchain approach to emission trading system in case of Finland?*

This study is novel because even though there has been numerous research on blockchain application for ETS, there has been few research specifically on the key determinants impacting trust. Therefore, this exploratory research can be highly relevant for not only academic workers in the field of blockchain application and CO_2 emission abatement, but also IT companies providing blockchain approaches and global institutions designing emission trading mechanism. Along with other stakeholders involved in ETS.

The paper will continue on revising literature of blockchain technology, emission trading mechanism, existed blockchain application on ETS. Subsequently, relevant trust literature will be analysed before proposing a conceptual model with 5 preliminary trust determinants. Afterwards, the 2 in 1 exploratory research design will be displayed, meaning grounded theory approach for empirical papers plus interpretative approach for three expert interviews. Therewith, the research will verify the 5 proposed preliminary trust determinant, suggest 1 new determinant, and propose two models of different trust factors based on the qualitative data found. After that, an insightful discussion will be conducted when a consolidated model with verified trust determinants and influencers will be proposed. Ultimately, the Conclusion Chapter will analyse the reliability and validity of the whole research.

CONCEPTUAL BACKGROUND

2.1 WHAT IS BLOCKCHAIN?

Blockchain is one of the emerging technologies stressing on models and innovations of the Internet of Things (IoT) and artificial intelligence (AI) revolutions (Abou Jaoude & Saade, 2019). The technology was born along the publication made by Satoshi Nakamoto creating bitcoin, which depicted the technology as a distributed peer-to-peer (P2P) network-structure, used to overcome obstacles of maintaining sequence of transactions, so as to avert repetitive-spending problems (Nakamoto, 2008). Blockchain is a P2P structure that allows its users to verify, store the same data simultaneously (Ali et al., 2021). It represents append-only ledger like a diary that records and maintains all transactions between users solely in chronological or timestamp sequence without reversible possibility (Casino et al., 2019). It is a shared ledger system where transactions of non-trusted parties can verifiably be conducted in a network without being monitored by trusted authority, an efficacy of decentralisation (Christidis & Devetsikiotis, 2016). Therefore Liu et al. (2019) delineated that decentralisation, irreversibility immutability, together with non-repudiation, and transparency, are the unique advantages of blockchain technology.

In contrast to conventional web solutions of client-server model with authorities gripping control of users' data (Ölmez & Karaarslan, 2019), each participant of a blockchain has an identical copy of the ledger named “nodes”. These nodes assemble transactions into blocks that are judges of whether transactions are valid thus included, otherwise which are invalid thus excluded from the blockchain (Casino et al., 2019). Each node contains a complete copy of all transactions within the blockchain and is capable of reading, making legitimate changes as well as write a new block into the chain via a self-regulating system defined since the blockchain was created (Casey & Vigna, 2018; Chen & D Lloyd, 2021).

TYPES

Blockchain networks are categorised into two types: permissionless and permissioned. Again created along with the birth of Bitcoin and blockchain ledger by Nakamoto (2008), permissionless is an open form of blockchain which guarantees access for all actors worldwide, for instance Bitcoin, to obtain and exchange the cryptocurrency (Smits & Hulstijn, 2020). Ethereum, the second biggest cryptocurrency and the biggest blockchain platform in application, is also a permissionless platform, entailing that anyone in the world is allowed to participate, albeit naturally someone needs the knowledge and resources to mine in order to participate. At nowadays settings though, Ethereum has also popularly been adapted in a permissioned format (Polge et al., 2021).

Due to market need for enterprise privacy among other reasons, another pattern called permissioned platform, has been more widely adopted, where only authorised entities are capable of accessing or modifying the ledger (Smits & Hulstijn, 2020). A fork blockchain of Ethereum called Quorum, innovated by J.P. Morgan and owned by ConsenSys since 2020 (Irrera, 2020), is a permissioned ledger, in which although public transaction is possible yet exclusively viewable for the commissioned participants, not for general Ethereum users. Additionally, Corda blockchain, developed by R3, is an open-source permissioned ledger system, where each note is obliged to confirm its permitted identification before accessing transactions of the network (Polge et al., 2021). The difference between permissionless and permissioned substantially is a reflection of their different regulating systems that let participants of a blockchain reach multilateral trust.

CONSENSUS MECHANISM

The self-regulating system of a blockchain is a cryptographic protocol that each participant of the chain is consent with. That is why it is also called *consensus mechanism* or *consensus protocol*. It regulates how nodes should authenticate or verify transactions (Casey & Vigna, 2018). Every block in a blockchain has a cryptographic hash of previous block, a timestamp, and its transaction data, thus all blocks are connected after verifying by the nodes (Narayanan et al., 2016). Once these blocks are chained as a growing catalogue, the chain becomes practically immutable and deletion-resistant, tamperproof, and unmodifiable by any single actor (Chen & D Lloyd, 2021). A cryptocurrency is defined as a form of digital asset or virtual currency, based on a distributed ledger system, but many cryptocurrencies are based on their own decentralised networks with own consensus protocols. Crypto tokens are the denomination of a certain cryptocurrency, corresponding to an asset or usage on their blockchain (Narayanan et al., 2016).

Moreover, a full node is defined as computer that hosts its whole blockchain and is willing to fully validate the transactions (blocks) (Casino et al., 2019). Capacity of a full node computer is presently required to be minimum 389 GB (Stastista, 2022). This threshold only grows bigger with the development of the technology (Redman, 2018). Whereas a partial node does not have the complete ledger and it can only download a part of the chain permitted (Hendrickx et al., 2018).

Depending on the blockchain type, various consensus mechanisms exist (Mingxiao et al., 2017). The classic and hitherto most popular consensus is Proof-of-work (PoW), created along with bitcoin by Nakamoto (2008), which requires resolving sophisticated computational process, named cryptographic puzzle, like finding hashes with particular patterns, for example a leading number of zeroes for authentication and verifiability (Antonopoulos, 2014). Participants of the computational process are so called “miners”. The more miners join the network, the more difficult it is to solve the cryptographic challenge and they maintain mining as long as the reward is larger than their electricity and hardware costs. That has led to the major drawback of blockchain technology with PoW mechanism: the fiercer the competition of gaining mining reward it is, the more electricity-intensive it becomes. PoW is proved unsustainable towards global environment over a long period thus significantly impeding the scalability of blockchain technology (Casey et al., 2018). Taking an example of mining process of Ethereum, the second biggest blockchain system in the world, although it consumed a quarter to half of the electricity as Bitcoin mining, but its electric consumption in 2018 was still roughly equal to the national annual consumption of Iceland. A common Ethereum transaction cost more energy than an average American household in one whole day (Fairley, 2018).

As a solution to this obstacle, developer has invented Proof-of Stake (PoS) consensus mechanism, which divides stake proportionally according to the present wealth of miners, instead of splitting blocks across uniformly to the relative hash rates of miners (Pilkington, 2016). Within this protocol, a larger stake owns a validator equitably more opportunities at a turn, meanwhile a validator once discovered cheating, would lose profoundly (Fairley, 2018). In essence, all nodes in a blockchain follow one voting mechanism, those who own more underlying assets, obtain a bigger voting share in validation (Smits & Hulstijn, 2020).

Although more time needed to mature, emerging blockchain platforms like Ethereum, vowed to switch to PoS incrementally since created. The founder of Ethereum Vitalik Buterin, stated that “switching from PoW to PoS would cut the energy consumption per transaction in hundredfold”, due to remarkable deduction in power consumption and more developed scalability (Dannen, 2017; Fairley, 2018). In contrary to PoW, challenge of PoS is the potential phenomenon that the richer only grow richer along consensus implementation (Zheng et al., 2018). To tackle this challenge, Solana invented consensus method of Proof-of-History (PoH) as complementary of PoS for their blockchain architecture. With PoH, a leader validator node of a network, elected via PoS, verifies the passage of time between two sequential events. Thanks to the combined mechanisms, the data transaction speed of Solana can be four thousand times faster than Ethereum (Yakovenko, 2018). In fact, Bitcoin, Ethereum and Solana are all permissionless blockchain.

Moreover, there have been innovations in blockchain protocols, within which Practical Byzantine Fault Tolerance (PBFT) consensus, adopted by Hyperledger Fabric, is amongst the most influential. With this protocol, the consensus of the ledger system can still be achieved even if limited small number of nodes are falsified or behaving arbitrarily, as long as the chaincode (like public key) of all others operate correctly (Cachin, 2016; TRON Core Devs, 2020). Developed from BFT family but a more efficient consensus mechanism called Proof-of-Authority (PoA) was invented. It elects a mining leader, through strict procedures, to be in charge of proposing new blocks. Each participant is eligible to be elected as the authority with convinced reputation. The mechanism reduces the amount of messages required compared to PBFT hence it is more efficient, but it can bear challenge of unavailability and doubt of synchronisation (De Angelis et al., 2017). Although PoA is a favoured by enterprise clients with bigger concern of privacy, it actually foregoes decentralisation which is the core notion of blockchain technology. Binance, one of the biggest blockchain platforms, has adopted a combined mechanism of PoS and PoA which serves predominately the needs of permissioned blockchain customers like other platforms with BFT protocols (Binance Academy, 2020; De Angelis et al., 2017).

Besides all the consensus protocols described above, there are also Delegated Proof-of-Stake, Proof-of-Activity, Proof-of-Burn, Proof-of-Validation, Proof-of-Capacity, Proof-of-Importance, Proof-of-Existence, Proof-of Elapsed Time, Ripple Consensus Protocol, Stellar Consensus Protocol as well as Proof-of-Space-and-Time (De Angelis et al., 2017). Moreover, Polkadot Protocol, created by co-founder of Ethereum Gavin Wood, is rather unique by enabling interoperation between multiple blockchains of different mechanisms (like between PoW and PoS in one platform)(Web3 Foundation, 2022). Interledger Protocol has similar cross-blockchain interoperability with a focus on web payment inclusion (Siris et al., 2019).

The reason behind this large amount of mechanism variants is that there has not been a perfect blockchain solution. Although majority of them are evolvements of PoW, PoS and BFT. Each consensus mechanism has its inherent and applicational advantages and disadvantages. Depending on the blockchain application to particular industry or end-user, the most suitable mechanism design should be selected to achieve consensus among participants in the business network.

SMART CONTRACT

Appending to consensus protocol, the introduction of *smart contract* by Ethereum is a milestone in blockchain evolution. Ethereum endorses all genres of computations. It has an abstract layer facilitating any person to create own rules of ownership, own forms of transactions and own state of transition functionalities. That can be achieved thanks to the invention of smart contract, where a collection of cryptographic rules triggers only when certain criteria are satisfied (Vujičić et al., 2018). Smart contract is an important application of computable contract, within which, contracted terms automatically reinforce once certain determined performance is achieved, without manual interference (Wright & De Filippi, 2015). Owing to this application, Ethereum has become the most mature programmable blockchain platform for enterprises around the globe. Worth to highlight that smart contract technically does not need blockchain to function, it is simply coded conditions which will execute certain tasks grounded from pre-defined events. But it does significantly complement blockchain application and facilitate its synchronisation (Braden, 2019b).

2.2 WHAT IS EMISSION TRADING SYSTEM?

Imposing taxes and issuing tradable permits are unanimously recognised as the approaches of penalise and abate pollution emission (ICAP & World Bank, 2021; Spulber, 1985). The difference lies in how the monetary penalties are established: in regard to imposing taxes, the price is decided and fixed (at least over a period of time) by governmental bodies; in regard to tradable permits, the price is outcome of market value. Throughout abundant analyses and comparisons from different aspects and contexts over time, both methods could be effective depending on how to be implemented. There are pros and cons in both policies (Fishelson, 1976; Quirion, 2010; Shinkuma & Sugeta, 2016; Spulber, 1985; Weitzman, 1974).

Consistent with issuing-permit approach, Stavins (2003) defined emissions trading, also called cap and trade (CAT), as a marketing method or scheme of limiting pollution emission via injecting economic incentives to involved parties. A limit or a cap is established depending on type of carbon dioxide that the industries are permitted to emit. Equivalent amount of permits that allow participants to outlet GHG are then issued and distributed at the start of the period, either through free allocation or auction. At the end of the period, all parties are obliged to submit the amount of permits together with a report on the amount of emission generated in the course of that period. These permits are incentivised traded between participants. The ones hold excess of permits can sell them to their peers who produced more emission than they were permitted. Subject to the policy, in case that a participant fails to obtain sufficient allowance after a certain period, sanctioned offset may be adopted to counterbalance the over-emission (ICAP & World Bank, 2021). In this manner, this offset is an outcome of emission reduction in other places from other sectors. Hence, at a holistic scale, carbon neutrality is achieved (European Parliament, 2019; Khaqqi et al., 2018). European Parliament (2019) defines carbon neutrality as a state of net-zero CO_2 outlay in the society, which is promised to be accomplished before 2050 amongst EU territory. But in the case of Finland, focused by this study, they will achieve it by 2035 instead (Finnish Government, 2019).

Due to the exacerbation of greenhouse effect, issuing-permit approach has recent years been most popularly adopted for CO_2 emission, as illustrated above. However, the method was also applied against pollution emission like sulphur dioxide (SO_2), nitrogen-dioxide (NO_2). One of the most prominent CAT application cases in US is a programme intending to reduce emission of the key cause of acid rain -- SO_2 begun in 1990s, which ultimately reduced the emission till 10.2m tons in 2005 from 15.7m in 1990 (Chestnut & Mills, 2005). Meanwhile this CAT allowance trading method led to annual cost savings of $1 billion compared to utilising conventional regulatory controlling approach (Carlson et al., 2000).

Back to our research concern—carbon dioxide, adopting emission permits and trading method is considered empirically being able to alleviate climate change with minimum risks: 1) by accomplishing CO_2 emission target with monetized numeric values (caps), the trajectory of which starts modestly later more stringent incrementally thus initiating long-term investment; 2) by lowing cost uncertainty when countries develop sustainability mechanisms and cooperate with other countries' policies; more significantly, 3) by providing an option of hedging economic sacrifice via trading carbon allowances with establishing meaningful emission consensus domestically and internationally (Stavins, 2008).

Based on the global practices according to Kyoto Protocol, Pan et al. (2019) portraited the essential processes of carbon trading as below. In an ideal case, companies invested more in sustainable equipment and transformation would achieve carbon reduction. Companies whose emission exceeded their permission would need to buy leftover emission quota from them. In this manner, consciousness of lower carbon outlet should be accentuated. Eventually, facility, technology, sustainability management and other approaches will be enhanced, at the landscape level, thus emission-reduction and carbon neutrality are accomplished in a long run.

FIGURE 1 EMISSION TRADING PROCESSES (PAN ET AL., 2019)

The establishment of emission trading registry system aims to maintain integrity of ETS and avoid double counting. It acts as database which "issues, records, and tracks the carbon units exchanged within market mechanisms or financed through Results-Based Climate Finance programs" (Dinguirard et al., 2016). ICAP and World Bank (2021) asserts that "the registries must facilitate the creating, trading, and surrendering of all allowances within an ETS". Surrendering is defined as reporting and submitting emission allowances fully equivalent to a participated entity's annual CO_2 outlet quantity, towards the registry. Each entity within the scope of ETS is obliged to do it (Ellerman, 2010), otherwise, the entity faces a considerable fine. Naturally if an entity ends up more allowances than their actual emission, they are subject to sell them at the agreed markets as depicted above (European Commission, 2022b). Under EU ETS, the surrender deadline is 30th April every year and each allowance equals to 1 tonne of GHG (Dutch Emissions Authority, 2022b).

Contingent on time-consumption and resources a country requires for a registry, it is imminent for member countries of the Paris Agreement to designate a compatible market mechanism, considering legitimate, administrative, operational, and technological perspectives of national registry development (Dinguirard et al., 2016). For example, the Energy Authority is the registry for Finland (the Energy Authority, 2022), Dutch Emission Authority for the Netherlands (Dutch Emissions Authority, 2022a), German Emissions Trading Authority for Germany (German Emissions Trading Authority, 2022).

IMPLEMENTATION OF ETS

Implementation of ETS has varied among member states of Kyoto Protocol depending on each county's timeframe and decision processing. Many member governments began with a trial period to examine the viability and effectiveness of their designed system. For instance, EU had a trial period for testing their ETS as Phase One and China launched eight aerial pilots before developing their national system. Also, Kazakhstan had one-year testing phase (Akhmetov, 2015). While California did not undergo an official trial, they had a practice round of auctioning emission allowances within several relevant industries (CARB, 2014).

SOUTH KOREA

The *9*th largest fossil fuel emitter of the world, South Korea did not issue an official trial period (Tiseo, 2021), but they introduced a Target Management System (TMS) in 2012 as their first stage, which consisted of specific reduction targets and penalties to the carbon emission companies. TMS had made South Korea transition towards their ETS more steadily via MRV processes during TMS, which offered the government crucial data to define the overall cap and free allocation for the first version of ETS. Meanwhile the related emission companies also obtained the benefits of experiencing the carbon reduction costs and executing the policies before official Korean ETS was reinforced (ICAP & World Bank, 2021).

Following this knowledge and experiences from TMS, in 2015, South Korea launched their first mandatory national ETS in Asia named K-ETS thus they became the 2nd biggest carbon market in the world right behind EU ETS. K-ETS is imposed on 684 largest CO_2 emitting entities, occupying around 73% of national annual emissions. Within the Korean system, allowances can be traded in secondary market of Korea Exchange (KRX) and starting from Phase 3 in 2021, the certified financial 3rd-party agents can also participate. They are allowed to trade allowances and converted CO_2 offsets on KRX up to 200 thousand allowances per certified agent (ICAP, 2022). K-ETS had a revenue of 294.8 billion or USD 257.7 million in 2021.

MEXICO

Besides issuing trial period and self-testing system as a first stage, implementing a pilot project has been a widely accepted approach as the first step of ETS implementation. As the 8th biggest developing country in the world (World Population Review, 2022b), Mexico is the *15*th largest carbon dioxide emitter of world (Tiseo, 2021). They started their pilot ETS project in 2020 which will be operated for two years before one-year full transition period of 2022 meaning a 3-year preparation and test phase. As the first reinforced ETS operation in Latin America, the pilot project concerns 282 Mexican entities covering at least 100 thousand tonnes of CO_2 estimated to occupy around 40 percent of the total annual emission. Yet, this pilot was determined not to impose direct financial punishment to the noncompliant businesses, instead their holding emission allowances will be subtracted, and they would lose opportunities of banking allowances at the pilot project as well as latter official ETS stage (ICAP, 2022; ICAP & World Bank, 2021).

CHINA

On another hand, the *largest* carbon-emitting country China, occupying over 30% of the global CO_2 emission (Tiseo, 2021), have started their implementation efforts much earlier.

The 3rd biggest country by area in the world launched their ETS pilots incrementally amongst 5 major cities and 3 provinces between June 2013 and December 2016 covering total population of over 300 million (Zhang et al., 2014). Different from the latter Mexican pilot approach, the Chinese pilot program of each region had substantial variations accustomed to regional socioeconomic differences. For instance, the free allocation method in Shenzhen and Chongqing was rooted from grandparenting; in Shanghai and Hubei Province was based on benchmarking; whilst Guangdong Province adopted some extent of auctioning. Moreover, the targeted sectors also varied by region, for example although energy-related sectors were included in all pilots, domestic aviation sector was included in Shanghai, Guangdong, Beijing, and Fujian, construction sector only in Beijing and Shanghai, and public transport solely in Beijing and Shenzhen. The outcome of the pilots was significant because the cumulative allowance transaction was 282 million tonnes of carbon worth of CNY 6.2 billion or EUR 787.4 million till the end of 2018.

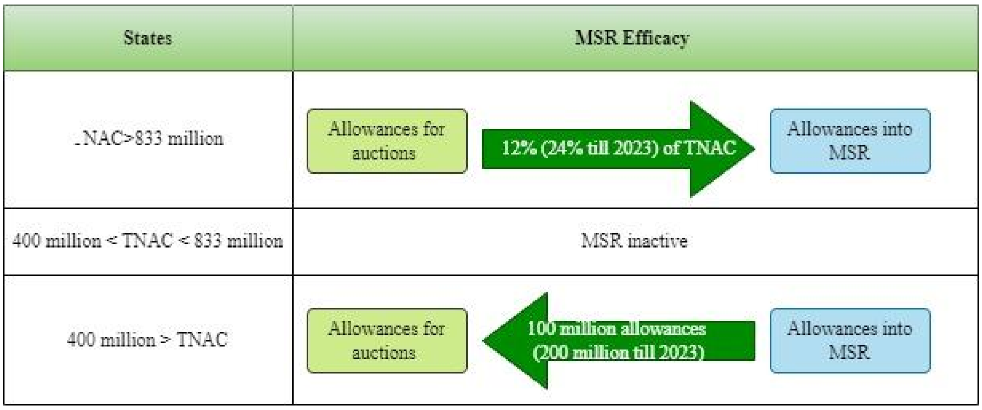
This variation tactic allowed the Central Government to conduct comparative analyses on pros and cons of each regional pilot in order for a best-fit national ETS (ICAP, 2019; Zhang et al., 2014). With the success and experiences absorbed from various pilot programs, in 2021 China officially issued their national ETS which concerns 2162 entities of energy-related sectors covering approximately 26 thousand tonnes of CO_2 annually (ICAP, 2022).

EUROPEAN UNION

As the first adopter of developing emission trading system according to Kyoto Protocol, the EU encountered a defeat from the outcome of Phase 1 (2005-2008) or the trial period, which predominately resulted from overdistribution of emission allowances. That led to significant depreciation of the allowance price thus effect of incentivising and penalising was generally abated. Other lessons gained from the trial period were: 1) lack of holistic synergy between Member States; 2) an amount of allowances was unnecessarily allocated among lesser-emission sectors. They resulted in unbalanced emission trading between certain states and sectors in the carbon market (European Commission, 2008). At Phase 2 (2009-2012) the Union revised and discussed the referred causes and outcome combined with the huge impact of 2008 financial crisis. Subsequently within 3rd Phase (2013-2020) of EU ETS, both development processes of the cap and approach of free allocation were centralized, negotiated, and standardised at the highest Union level. Moreover, free allocation of emission allowances is only permitted for sectors with issue of carbon leakage (European Council, 2009). Carbon leakage is defined as one country’s GHG increase due to the gas emitted by another country with stricter regulation (Cala, 2014).

Additionally, from Phase 3 onwards, EU agreed to adopt a robust strategy allowing adjustment and amendment during the implementation of the same phase contingent to global environmental and financial changes. In order to alleviate the negative effect of allowance surplus, EU adopted a short-term approach of suspending carbon market auctions till 2019-2020, but for a long-term strategy, Market Stability Reserve (MSR) was established and has been in practise since January 2019. It is a major amendment to EU ETS introduced at Phase 3 and expected to substantially enhance resilience against disruptive volatility at EU carbon trading market, especially into the 4th Phase (2021-2030) (ICAP & World Bank, 2021).

MSR introduces a concept of Total Number of Allowances in Circulation (TNAC) which is the outcome of allocated allowances minus verified emissions or cancelled allowances. When TNAC value is above upper threshold, a predetermined percentage of the surplus is beheld from auctions, the actual adjustments of which will take place over the next calendar year; if TNAC is between upper and lower thresholds, MSR is inactive; if TNAC is below lower threshold, a predefined amount of allowances is released from MSR back to auctions, the actual adjustments will again be activated over the subsequent year (European Council, 2015).



States	MSR Efficacy
.NAC>833 million	Allowances for auctions → 12% (24% till 2023) of TNAC → Allowances into MSR
400 million < TNAC < 833 million	MSR inactive
400 million > TNAC	Allowances for auctions ← 100 million allowances (200 million till 2023) ← Allowances into MSR

FIGURE 2 THE EU ETS MARKET STABILITY RESERVE (ICAP & World Bank, 2021)

The TNAC is announced by European Commission before mid-May each year to inform trading parties of the MSR activity status of that year (Ballesteros et al., 2019). The current thresholds and MSR allowance operation concurred by EU is displayed as Figure 2, but European Commission is set to revise these parameters every 5 years after 2021(European Council, 2015). But starting from 2023, allowances beheld in MSR will not be allowed to exceed the total amount of emission allowances actioned within the former year. Consequently, holdings of the excess amount are subject to be invalidated (ICAP, 2022). Along with the operation of MSR, year of 2019 saw 397 million carbon allowances deposited into the reserve and in 2020 more than 375 million allowances withdrawn occupying 35% abatement in auction quantity for that year. Furthermore, 320 million allowances were placed into the reserve in 2021, signifying almost 40% reduction of auctioning volumes (ICAP, 2022).

FINLAND

Finland has a sustainability tradition of bioeconomy and circular economy due to the early sense of urgency amongst their large forest firms (Näyhä, 2019). The country has adopted EU ETS since the start. Consistent with the fact that EU ETS covers a bit over 40% of CO_2 emission from the member states, the ETS covers nearly half of Finnish emission. The emission allowances are allocated for free or via auction among the concerned entities, who can trade these allowances either within Finland or in other European markets (Ministry of Economic Affairs and Employment of Finland, 2022b). In reality though, most tradable allowances in Europe have been auctioned on the common platform European Energy Exchange (EEX), which is contracted by 25 EU member plus 3 EEA states. Only Germany and Poland opted out and have own designated platforms. Auctions are held 3 times per week at EEX and weekly or biweekly at opt-out markets (Ministry of Economic Affairs and Employment of Finland, 2022a).

The Finnish concerned scope for energy sector is more stringent than EU. Under the EU ETS, only energy providers producing over 20 megawatts are enlisted whilst in Finland heating providers producing below 20 MW are being regulated. Moreover, at the governance level, until 2020, Ministry of Economic Affairs and Employment has been in charge of deciding allowance allocation for energy sector and manufacturing sector, but from 2021 onwards (Phase 4 of EU ETS), these responsibilities are shared between the Ministry and the Energy Authority (Ministry of Economic Affairs and Employment of Finland, 2022b). As for aviation sector, the emission allocation, trading and monitoring responsibilities are shared between Finnish Transport Safety Agency (Trafi) and the Energy Authority (Ministry of Economic Affairs and Employment of Finland, 2022c).

Besides the three sectors already applied EU ETS, Finland has proactively resonated with EU's new proposal of "Fit for 55 laws package", which aims to achieve 55% CO_2 abatement in 2030 as a milestone towards final target of net-zero in 2050. Following the proposal, Finland designed a roadmap for establishing national ETS only for transport sector and building sector. This national system can be fully implemented before 2026 in case there will be delay in EU ETS expanding to the referred industries (ICAP, 2022).

CHALLENGES OF ETS

As elucidated above, ETS has been and will be a crucial approach to mitigate climate change, which is harmoniously concurred over the world. However, it is equally important to realise other challenges ETS has encountered besides allowance value depreciating mentioned above. For instance, Skene and Murray (2017) showcased an example of fraudulent behaviour due to non-transparency under EU ETS. ČEZ group, the energy conglomerate of Czech Republic, were allocated 30% of the country's allowances freely. To generate profits, they formulated a tactic of selling the carbon credits when the price was high and purchasing when they were cheap. This cumulated profit was, however, spent in increasing their coal production. In the end, the GHG emission of the country had increased rather than decreased. This case disclosed EU ETS lacking transparency of entities' emission behaviour off the carbon trading market.

Another issue is that there has not been a unified trading market in Europe let alone over the world. Even though 25 out of 27 EU countries, together with the EEA states, trade in a common market, the top two biggest CO_2 emitters Germany (7.72 tonnes per capita in 2020) and Poland (7.71 tonnes per capita in 2020) decided to opt out and operate their own auctions separately (Ministry of Economic Affairs and Employment of Finland, 2022a; World Population Review, 2022a). If we zoom out to the whole world, although the largest emitter China has reinforced their national ETS, the second emitter US has only a few State-level ETSs developed, the 3rd and 4th biggest emitters India and Russia even at the regional trial stage (ICAP, 2022; World Population Review, 2022a). Hence the integrity and consistency of ETS are factually absent heretofore.

2.3 HOW IS BLOCKCHAIN APPLIED?

Blockchain application embarked in traditional sectors like supply chain (Dujak & Sajter, 2019), financial (Qiu et al., 2019) and food safety (Kamath, 2018). Although such application practices have since then diffused into all other industries, for instance music and arts (Baym et al., 2019; Zeilinger, 2018), social service (Grover et al., 2019) animal protection (Button, 2020; Ölmez & Karaarslan, 2019), as well as credential governance (Young & Verhulst, 2018). Bao et al. (2020) utilised scientific approach and highlighted key blockchain application cases in various sectors: data management field (Dai et al., 2019; Karafiloski & Mishev, 2017), healthcare sector (Azaria et al., 2016; McGhin et al., 2019), Internet of Things (Alladi et al., 2019; Sharma et al., 2017), software-defined networking (Yazdinejad et al., 2020) and cybersecurity (Singh, Click, et al., 2020; Singh, Parizi, et al., 2020). Knowing blockchain has been widely applied, this research concentrates on its applications in energy sector, especially in the field of pollution emission management and emission trading.

There have indeed been blockchain application cases of managing pollution emission. One of the early published applications was IBM Hyperledger cooperating with Chinese government to track CO_2 emission dating back in 2017. They claimed to have conducted a successful pilot project and operated a joint-laboratory Energy Blockchain Labs Inc. in Beijing for emission tracing in China (IBM Corporation, 2018). Even though the outcome of this application has not been known, in 2021, the Chinese government has constructed a new corporation with Ant Group Blockchain, an affiliate of Alibaba, for CO_2 tracing, trading and auditing as continuous incentive for their road to carbon neutrality in 2060, following their commitment of ratifying the Paris Agreement (Gkritsi, 2021).

On another hand, Liu et al. (2019) aimed to boost the efficiency of Taiwanese carbon footprint validation through applying blockchain. They created a blockchain application framework of three layers, which from bottom to top are: calculation layer, integration layer and blockchain layer. In essence, calculation layer collects and calculates carbon footprint through IoT receivers; blockchain layer stores the claimed carbon footprint from certified enterprises for trading; integration layer acts as database that assembles data from other 2 layers, verifies them and provides access to the third-party carbon footprint retailer (Liu et al., 2019). This framework could be problematic since the role of blockchain is not significant and it does not enhance trusts of traders via decentralisation because the integration layer basically acts as a governmental body to validate carbon data.

EMPIRICAL BLOCKCHAIN APPLICATIONS TO ETS

Khaqqi et al. (2018) proposed a blockchain-enabled emission trading scheme model with reputation credits (BCRB system) as a complement to the existing conventional ETS and developed a profound case study for their scheme. This model utilised blockchain technology and smart devices on 1) the step of monitoring, reporting and verification in ETS, 2) forming a reputation-based trading system containing two mechanisms, market segmentation mechanism and priority-value-order mechanism. Even though emission transactions of the model were conducted at a blockchain environment, the process of issuing, allocating and surrendering allowance was not altered. Smart devices were introduced to the model because Khaqqi et al. (2018) believed blockchain is only capable of ensuring the immutability of the emission data already entered but the accuracy of the data to be surrendered relied on untampered smart meters.

An open source blockchain platform, Multichain was chosen to perform their case study, because the platform was embedded with a feature to delineate certain nodes to only perform the actions permitted by the blockchain administrator in the ETS (Khaqqi et al., 2018). At their proposed BCRB system, there were four types of nodes, or actors: a) Authority, to issue allowances, b) Firms, to buy or sell allowances, c) the Project, mainly as a seller, d) the Auditor, to give reputation points to the firms. Another feature of Multichain adopted by their case was stream (Greenspan, 2016), which functioned as the trading platform where bids and offers to carbon credits were published. The firm nodes could choose to collect, review, and select the bids and offers for a transaction from the stream.

The case imitated 3 companies A, B and C as participants of BCRB with context that A and B produced more CO_2 than their cap while C produced below it (Khaqqi et al., 2018). Meanwhile on the market there already published eighteen offers with asking price between $1.11 to 1.40 per carbon credit by sellers with different reputation points; fourteen bids with offered price of $1.24 to 1.39 per credit. Each of company then traded sensibly based on their contexts for the maximised benefit. Eventually A and B purchased sufficient credits to comply with their cap, C also sold their allowance with reasonable price on BCRB platform.

After the case study, Khaqqi et al. (2018) utilised a multi-criteria analysis to compare BCRB with conventional ETS. The BCRB had an obvious higher rating on stringency for non-compliance implying that it could prevent concerned entities from not complying with the emission regulations rigidly. The reason was that blockchain provided a more consistent and efficient mechanism to monitor, validate, and verify the actual emission of each entity. Compared to traditional ETS with inefficiency of avoiding double counting (Schneider et al., 2015), BCRB has been a blockchain application with native transparency by demanding majority acknowledgement for any validation (Khaqqi et al., 2018). On the other hand, regarding cost efficiency, conventional ETS was high rated meaning that it could reach certain goals without extra financial nuisance. Although the authors argued the investment should be “on a suitable level to inspire technology adoption.”

The promulgation of combining blockchain application with reputation-based system for emission trading did not stop from Khaqqi et al. (2018), one year later Liang et al. (2019) also proposed an application approach by introducing double-blockchain structure. The researchers from China utilised two blockchain for emission trading: one being confirmation chain, another being financial chain in order to improve the trading speed as well as transaction security. The two chains were asynchronous, a buyer began on confirmation chain to look for the suitable allowance and confirmed the order which, after being verified, created a new confirmation block. The same moment all trading information, such as nodes' public key, reputation points, quantity) was transmitted to financial chain via communication bridge (like Polkatdot). Financial chain then transfers the funds and allowances meanwhile a new legal financial block, after being verified, was asserted into financial chain. Along the completion though, a transaction fee was appended contingent to the reputation points of the buyer entity (Liang et al., 2019).

Although less comprehensive, Liang et al. (2019) also conducted a case study on their proposed ETS and confirmed the two chains operate with consistent trading outcome through decentralised processing. There were convincing results displaying that in a long run, due to the transaction fees depending on the reputation level, the concerned carbon emitters would be successfully incentivised to invest in reducing emission for better reputation, which was also one of the conclusions from Khaqqi et al. (2018). In the end, the authors were convinced that double-blockchain structure can enhance the transaction efficiency. It is also important to note that, smart meters should be deployed to acquire accurate emission data from the entities, which is de facto consistent with the design of BCRB system as well (Khaqqi et al., 2018; Liang et al., 2019).

Actually, back in 2014 the Chilean Government, collaborated with the World Bank, already had a successful pilot project of capturing precise renewable energy consumption and CO_2 emission data, synchronously registering the data into blockchain. The accurately collected data was lively displayed on a dashboard to general public during the project (World Bank, 2020). That provided pragmatic prerequisite for applying blockchain to collect, transmit and visualise energy and emission data precisely combined with smart meters.

Richardson and Xu (2020) proposed a hybrid model combining decentralisation, with application of blockchain-enabled token, and existing ETS authorised body. The researchers envisaged two types of tokens: emission, as one tonne of CO_2 verified emissions; permit, as permit to emit one tonne representing both allocated allowance by authority, or carbon credits granted by a verifier. The authority could mint permit tokens contingent to the cap then they were issued via either direct allocation or auction. Then these permit tokens were given to company entity once approved by a verifier. On another hand, any company could mint emission tokens if a verifier approved the transaction echoing the factual emissions of the company. Permit tokens could be traded without restriction among participants, who might also generate derivatives like swaps or options, otherwise send for an exchange. Token exchange here meant companies could trade their permit tokens with the authority. To guarantee market liquidity and token traceability, the researchers would adopt Bancor protocol to “automate price determination through a smart contract” (Hertzog et al., 2018; Rosenfeld, 2017). Moreover, emission tokens were burnt when an equivalent or larger amount of allowance or carbon tokens were sent in the same transaction, which was automated by smart contract. This also allowed any company to surrender their redundant permit tokens voluntarily same as EU ETS (Richardson & Xu, 2020).

A case study was also demonstrated by Richardson and Xu (2020), the proposed two-token system with execution of smart contract appeared to be consistent with the outcome of double-entry accounting. Necessary to note that this case study was conducted on open-source Ethereum. The reason was German’s and Mexico’s Environmental Ministries compared Bitcoin, Ethereum, Hyperledger Fabric and EOS platforms as climate policy applications in 2019. (EOS is a public blockchain on Delegated PoS mechanism with smart contract feature. It claimed to eliminate transaction fees and it was proved to be 266 times more trading-efficient than Ethereum (Arti, 2021; Xu et al., 2018)). In regards to programmability, operation cost, safety and usability, Ethereum and Hyperledger Fabric outstood others to be the best candidates of hosting ETS blockchain implementation (Braden, 2019b). Although Richardson and Xu (2020) underlined that either Hyperledger Fabric with tailored configurations or entirely customised ledger should be better option to host large-scale ETS in near future.

2.4 How is Blockchain application trusted?

This research acknowledges definition of *trust* from an economic perspective, which means the trustworthiness between end-consumer and provider (or between trustor and trustee) amongst business transactions (Gambetta, 1988). Depicted as the base of any commercial behaviour, trust is considered as the foundation of ecommerce (Keen et al., 1999). Pavlou and Gefen (2004) pointed out that trust is built up between business actors when one party has sufficient confidence that the other parties act according to their capability, integrity, and benevolence while trading.

Proposed Trust Determinants

Researchers found that one of the first factors business participants considered when judging the trustworthiness of a P2P application was whether the interface appears to be trustable, emphasis on the significance of a trustworthy look. Also, the users judged it by evaluating if functionalities of the application actually worked smoothly as they anticipated. Researchers defined these two elements together as situational normality, a key trust determinant for users or potential users to decide if they could trust a P2P application to be adopted amongst their business transactions (McKnight et al., 1998; Xu et al., 2005). But how could an interface look trustworthy? McKnight et al. (1998) further illustrated that a situationally normal interface should have its elements organised in reasonable manner. Its appearance should also enable users to achieve their goals through the application. A metaphor can be you tend to trust medical advice from someone dressing a lab coat with stethoscope on his neck than someone without (Tan & Thoen, 2000).

If user trusts an application because of its situational normality, this application is considered gaining situational trust. Gefen et al. (2003) and Xu et al. (2005) categorised situational trust as one of the two types of institution-based trusts, it relies on whether users' envisaged functions turn out operate normally and whether the application appearance seems to be typical and rational, which can be based on their former affiliated experiences. Hence this study proposes the first proposition to be verified later is as below:

Proposition 1: *the belief in situational normality influences the trust in applying blockchain technology to ETS.*

Conventionally, written contracts and agreements between buyer and seller guarantee trust. Whereas in digitized era, Vermaas et al. (2010) raised the concept of technology-based trust, where trustor and trustee count on mechanism or protocol of the technology, that operates reliably and expectedly. It is more of an abstract trust when technology-adopter or the stakeholders in a business network using certain technology, have sufficient confidence that the mechanism behind a technology operates consistently. Meanwhile they have beliefs that the provider of this technology is capable of offering maintenance service to ensure the consistency.

However, Smits and Hulstijn (2020) argued technology alone may never provide sufficient trust regardless of its mechanism, hence there always requires certain form of reliable regulator to oversee the business network. This echoed a classic inter-organisational trust factor approved by McKnight et al. (1998): a belief in structural assurance, which constitutes of 1) regulations or standards that ensure actors to behave disciplinarily, 2) legal guarantees that mitigate arbitrary risks. This belief was identified as the second type of institution-based trust following situational normality (McKnight et al., 1998). Xu et al. (2005) contextualised the concept in P2P application. They highlighted that structural assurance belief means trusting technological protection of the application offers, as well as trusting the credibility brought from certain self-regulation institution who guarantees users' privacy and security. On the contrary, if a user believes that the arbitrary risks would not be insufficiently alleviated by structural guarantees, one's trust in this technology will naturally be lowered (Tan & Thoen, 2000).

Proposition 2: *the belief in structural assurance influences the trust in applying blockchain technology to ETS.*

Smits and Hulstijn (2020) also claimed that technology-based trust is influenced by not only institutional trust but also party-based trust, which signifies different parties of a transaction or stakeholders of business network believe in each other due to historical reputation or interactions. For instance, various parties of a transaction trust each other because they understand the objectives and capabilities of the other parties in a sensible way. They also truly believe they can get what they expect from the others, which is the reason why they participate in the same network (Tan & Thoen, 2000).

In this sense, party-based concept resonates with the concept of peer-network normality introduced by Xu et al. (2005) and proved as one of users' trust determinants of adopting P2P application. Different from other types of trust, peer-network normality was defined as belief in the benevolent and low-risk endeavours of peers within a business network even if these peers are unidentifiable amongst each other in real life. Xu et al. (2005) further elucidated that this peer-normality belief can be attributed to either first-hand experiences using the application or second-hand knowledge from journey, media. To distinguish from the party-based trust that Smits and Hulstijn (2020) defined "party" as both institution and peer, we propose the 3rd key trust determinant as peer-based trust for this exploratory research as below:

Proposition 3: *the perceived trust between peers of a network, even unacquainted, influences the trust in applying blockchain technology to ETS.*

Additionally, findings of Shin (2020a) demonstrated that once users approve the transparency and accuracy of an algorithm, they tend to allow this algorithm to gather more personal information, that reversely lets the trusted algorism generate better and more clinical results. Therefore, a virtuous trust cycle can be formed where the trust between user and this protocol of certain technology shall be enhanced over time. Once a virtuous cycle is developed, technical advantages of blockchain such as security, transparency, and unforgeability, will only be magnified within the business network (Liu & Ye, 2021).

Nevertheless, it is a matter of fact that knowledge of blockchain is yet well spread over the world. Hence users or potential users' level of awareness and comprehension about the technology can remarkably influence their abstract trust in its application (Shin, 2020b). This accentuation of user's present understanding reverberates to another trust determinant of adopting P2P application proposed by Xu et al. (2005), knowledge-based familiarity. Although there are countless blockchain mechanisms (see also Section 2.1), this study delineates the familiarity a basic knowledge of how blockchain functions. Herewith, we propose familiarity with the technology itself to be a trust antecedent while applying blockchain.

Proposition 4: *the knowledge-based familiarity influences the trust in applying blockchain technology to ETS.*

Much has been illustrated about institution-based trust, which contains two types of trust: situational normality and structural assurance (McKnight et al., 1998). This trust originates from the fact that most trust relations in the society are held by verification institutions, usually legal intermediaries (Zucker, 1986). Smits and Hulstijn (2020) asserted trusts are generated in these institutions due to their reputation. People are confident that mechanisms behind verification institutes are to a large extent in controlled by reliable hands. Thus, trust is engendered not necessarily because of the existence of authorised institution but because of the trustworthy and verified control that user can rely on. Consistent with which, Tan and Thoen (2000) raised a concept of control-based trust as a salient component of business transaction trust, construed as user's belief in the procedures and mechanisms being able to avert frauds. The two researchers argued during any form of transaction, if parties do not trust each other in real life, they must be able to use "functionally equivalent control mechanisms to monitor and control the transaction performance", in order to reach consent (Tan & Thoen, 2000).

Smits and Hulstijn (2020) embraced this concept considered it to be another complement for technological trust. They argued a user can trust a technology when one believes that the mechanism, ensuring business transactions conducted properly, is controllable and verifiable within competence of the participant. Moreover, the case analysis Smits and Hulstijn (2020) confirmed the technological control brought by blockchain application can replace at least some forms of traditional institution-based trust. Furthermore, Shin and Bianco (2020) discovered business participants may build up trust in blockchain application if they feel their experience of the application procedures trustable, even without prior comprehension of the technological aspects. Therefore, this study proposes a fifth trust determinant as below:

Proposition 5: *the perceived control-based trust in mechanism influences the trust in applying blockchain technology to ETS.*

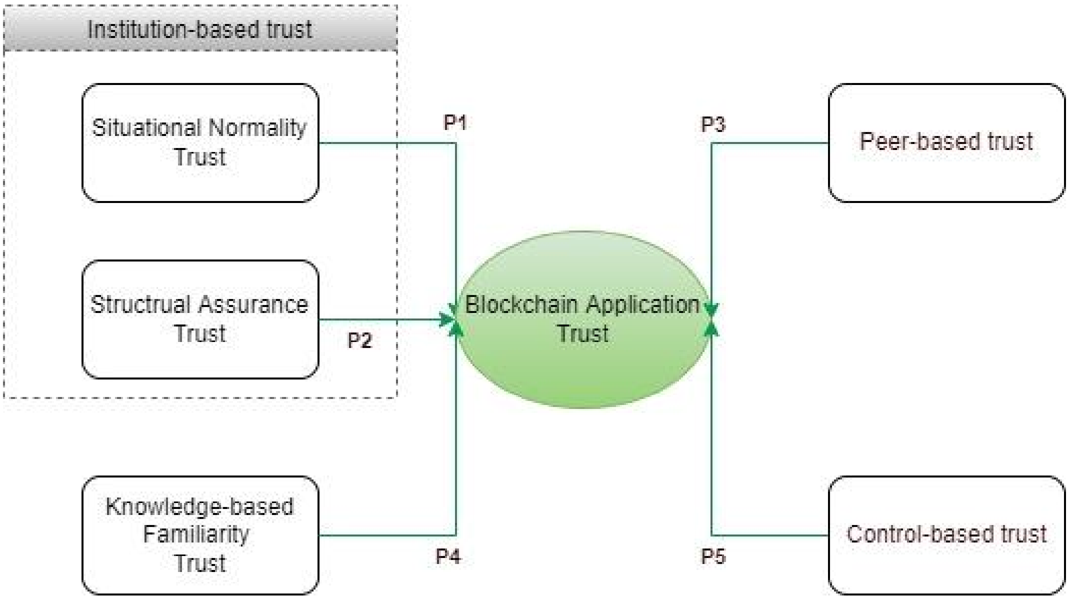


FIGURE 3 TRUST DETERMINANTS EXPLORATORY MODEL FOR BLOCKCHAIN APPLICATION

Therefore, based on the five propositions disclosed in this section, the study has formulated a preliminary model of reaching trust for applying blockchain as above. All these proposed trust factors will then be contextualised and verified from the perspective of implementing blockchain to ETS in Finland, through the empirical research section as follows.

RESEARCH DESIGN

Due to the fact that blockchain application had barely emerged till 2015, meanwhile the Paris Agreement, an official call for revising and upgrading CO_2 ETS, had not been in force until 2016. Hitherto there has been limited research and literature regarding applying blockchain technology to ETS in general, let alone particularly in the Finnish market. Hence this paper has chosen exploratory methodology to gather and analyse qualitative data, further in order to both answer the research question and explore in-depth understanding of trust determinants when applying blockchain to emission trading system (Sekaran & Bougie, 2016). Two phases of qualitative research have been conducted: external archival research as Phase One, interview research as Phase Two.

3.1 DATA COLLECTION

At phase one, five in-depth empirical reports plus three academic papers were selected to generate qualitative data. The five reports have showcased blockchain application to ETS including various country-specific case studies, also they were rather newly published stretching from 2018 till end of 2021. The second reason is that they are extensive reports with numerous trust elements related to blockchain application. Moreover, these reports offer pragmatic knowledge of how blockchain has been applied and will be applied to ETS combined with regulatory wisdom of Mexican and Swedish ETS. Especially Swedish system can be a highly relevant reference to Finnish system due to close ties between the two countries.

On the other hand, three academic paper was chosen. Firstly Mihaylov et al. (2018) displays why and how NRGcoin rewarded renewable energy users with trust created by smart contract. NRGCoin was co-created and introduced by an expert participated in our interview and was frequently referred in blockchain-application papers as a prominent use case. Secondly Wu and Tran (2018) gives an investigation of applying blockchain to sustainable energy. This highly relevant research had been cited over 190 times in less than four years since published, representing remarkable credibility in blockchain-application field. Thirdly, Nguyen et al. (2021) proposes a new ETS for vehicle emission tracing utilising blockchain, together with an extensive case simulation, thus an empirical instance of high pertinence. Additionally, we found imperative to introduce academic leverage on the five rather consultant-oriented reports for higher research validity. Finally, none of these academic papers are included at Conceptual Background chapter, hence they do not overlap with the referred literature at Discussion chapter.

These eight articles, with profound amount of "*trust*" repetition altogether, were examined to verify the five proposed key trust determinants from the preliminary model of conceptual background. Notably, when scrutinising "*trust*" iterations, only the ones in context of blockchain being applied were accredited, whereas the ones in context of blockchain not being applied due to certain reason related to trust are classified as irrelevant. Also, "*trust*" iterations within collocations such as "trusted third-party,", "trusted registry", "trusted technology" were labelled irrelevant because they were not pertinent to achieving trust. New trust determinants can also be discovered through exploration amongst interviews, which will be displayed at Results Chapter.

Reports	**Published Time**	**Amount of *Trust* Iteration (Relevant only)**
Navigating Blockchain and Climate Action (Fuessler et al.)	Dec 2018	21
Blockchain Potentials and Limitations for Selected Climate Policy Instruments (Braden)	Mar 2019	5
Blockchain for Mexican Climate Instruments Emissions Trading and MRV systems (Braden)	May 2019	3
Infrastructure for Article 6 MRV and transfers –the potential of blockchain-based technologies (Fuessler et al.)	Nov 2021	14
Navigating Blockchain and Climate Action state and trend (Guyer et al.)	Dec 2021	9
Academic paper		
NRGcoin—A Blockchain-based Reward Mechanism for Both Production and Consumption of Renewable Energy (Mihaylov et al.)	Jun 2018	5
Application of Blockchain Technology in Sustainable Energy Systems: An Overview (Wu & Tran)	Aug 2018	13
B-ETS: A Trusted Blockchain-based Emissions Trading System for Vehicle-to-Vehicle Networks (Nguyen et al.)	Feb 2021	7
Total iterations		**77**

TABLE 1 EXTERNAL ARCHIVAL STUDY MATERIAL SELECTION

After that Phase Two proceeded the qualitative research with conducting 3 semi-structured interviews to obtain insight from expert interviewees to validate the key trust determinants. Based on accumulated knowledge illustrated through literature and archival research of Phase One, the author formulated generic interview bullet points but without pre-structured questions. Depending on interviewees' responses and interaction with the author, questions were asked in agile manner albeit predominately trust-antecedent centric. On the other hand, due to the variance in expertise, first interview concentrated on asking interviewees how various stakeholders involved in Finnish ETS achieve trust; whereas second interview focused on questioning how different parties reach trust while applying blockchain towards energy sector; third interview concentrated on asking how different user groups reach trust while using blockchain for climate-change projects.

3.2 SAMPLE

Sampling is concerned of the selection approach for interviewees of Phase Two. Judgment sampling technique was utilized to select 2 ETS experts and 2 blockchain-application experts. This technique was chosen because both emission trading and blockchain are rather novel concepts thus non-experts may not be qualified to provide with reliable qualitative data. Consistent with the condition stated by Sekaran and Bougie (2016), "specialized informed inputs on the topic area researched is vital" and other sampling techniques cannot serve our research objective.

As introduced above, every member state of Kyoto Protocol has their designated governmental department in charge of domestic emission trading within EU reinforcing EU ETS. In case of Finland, the Energy Authority (Energiavirasto) is the government body in charge (the Energy Authority, 2022) (see also Section 2.2). Meanwhile our research focuses on emission trading of Finland, hence interviewing ETS experts from the Energy Authority was obviously the most sensible choice for Phase Two. The author attempted to contact experts with ETS background employed by Energiavirasto via LinkedIn and email. Eventually two staff, with 13-year and 8-year emission trading experiences respectively in Energiavirasto, concurred to have a half-an-hour team interview at a virtual setting via Microsoft Teams.

Since this research is to investigate trust when applying blockchain to emission trading, whilst the interviewed ETS experts naturally did not have any pragmatic aspect of blockchain technology, this paper was long for at least one blockchain application expert to cover this void of interview data. Requests were sent towards most leading and contributing authors, related to European climate action, of the five empirical reports selected for Phase One. Finally, two experts passionately agreed on being interviewed by the author.

The first blockchain expert is leading author of one chosen report and one chosen academic paper. He agreed on having a one-hour interview virtually through Zoom. The expert, a PhD of computer science, is a co-founder of NRGCoin and Cocoa Collaborative Innovation, with expertise of blockchain application to energy trading since 2016 and owns six publications in this novel field. He is labelled as *academic blockchain expert* (or simply academic expert) in following parts of this research. Notedly, “academic” does not mean this expert has only scholar expertise of blockchain, only the fact that he is comparatively more academic than the second blockchain expert. As mentioned above, obviously he has profound empirical experiences too.

The second blockchain expert is leading author of 4 chosen empirical reports, who also concurred with a one-hour interview virtually on Zoom. This expert is the CTO of Gold Standard, a standard and certification entity founded by WWF in 2003, to ensure CO_2 abatement projects and other climate development activities under UN’s Cleaning Development Mechanism (CDM) (Gold Standard, 2022). He is started working on blockchain application projects against climate change since the birth of blockchain application (the creation of Ethereum) in 2015. This expert is labelled as *professional blockchain expert* (or simply professional expert) amongst latter parts of this research.

3.3 RELIABILITY AND VALIDITY

The holistic design of this research, being 5 empirical reports with 3 academic papers as Phase One; 3 interviews for two different research components of this research (blockchain application and ETS) as Phase Two, is aiming to maximise the reliability of qualitative data and further findings. Particularly the academic papers were appended to hedge potential risk of missing relevant aspects when generating axial and selective codes via grounded theory. Moreover, the interview with 2 Finnish ETS experts was conducted to fill the lack of Finland-specific data from Phase One, albeit required by our research topic. To guarantee the interview data reliability, the author stringently asked trust-oriented questions at the setting of emission trading to the Energiavirasto experts only, thus no questions about blockchain at the interview since they do not have expertise of that field. This manner ensures our research obtaining most reliable data from the experts in their own specialised field rigidly.

Internal validity is hard to be ensured for the reason that both blockchain application and ETS are emerging fields, hence there is a genuine lack of empirical use cases and academic papers, let alone a combination of both ends with research focus on achieving trust. However, eight papers with 77 relevant “*trust*” iterations processed by grounded theory, complemented by 3 interviews with 4 experts of unchallengeable expertise, have together maximised the internal validity in a restricted timeframe. That implies the research is structured to be profoundly relevant to the research question this paper aims to explore and discuss (see also Section 1.5). Additionally at data analytical stage (the section followed), properties of each relevant quote at Phase One are remained for final grounded theories; contextualising quotes was conducted before interpreting trust statements at Phase Two. Both measures were taken to endorse internal validity of this empirical research as well.

External validity is always an obstacle to qualitative research especially when it is exploratory as well. However, generalisability is heightened because all selected materials for Phase One were published recent four years with three of which published last year (2021). Meanwhile all four interviewees are currently still working in the same professional fields as their expertise. Hence the qualitative data collected should considered consistent with the nowadays socio-scientific situations. As introduced above (see Section 3.1), multiple use cases, although typically explicit, are included in the selected empirical reports, which should strengthen our external validity. Inevitably, the limited amount of interviews barricades an extensive generalisability of this study in spite of the mitigations mentioned.

3.4 DATA ANALYSIS

To ensure the exploratory research purpose, Elliott and Timulak (2015) argues flexibility as a requisite of analysing qualitative data. This study also employed two analytical approaches for the two phases, respectively. Grounded theory approach was applied for Phase One. Based on the iterative compilation and analysis out of real-world information (Delve, 2021), grounded theory is the best-fit method to serve not only inductive reasoning required by exploratory research but also deductive inference of scrutinising preliminary trust factors. Unlike conventionally starting with transcribing interviews, archival materials are papers that can directly be coded, hence the grounded theory approach for Phase One was conducted as four steps as followed: 1) extracting sentence(s) with “trust” elements into quotes per paper; 2) filtering out the irrelevant quotes (see also Section 3.1) and describing properties (context) of each quote per paper; 3) labelling quotes with properties with trust codes; 4) categorising quotes with properties per trust code and generating grounded points. These steps originated from the prestigious grounded theory approach guidelines proposed by Strauss and Corbin (1994).

Important to be noted that, some selected *trust* quotes with properties can be categorised into more than one trust codes although most of them was grounded for one determinant only.

Elliott and Timulak (2015) also emphasised on the importance of “constant critical self-reflection” on data analysis and end theories when qualitative research is conducted. Even though the interview data acquired could be more profound, Phase Two must play a critical role of checking and auditing the data from the preliminary model filtered by Phase One. Therefore, interpretive analysis approach was adopted for Phase Two with processes being: 1) transcribing relevant parts of interviews into quotes; 2) extracting trust-relevant quotes; 3) contextualising extracted quotes contemplated by experts' spoken contexts; 4) and interpreting contextualised quotes into trust statements; 5) combining and complementing grounded Phase One data per trust code. Grounded theory or other coding techniques were not selected for Phase Two due to the fact that "*trust*"-related iterations amongst interviews are limited. In order to maintain completeness and maximise value of the interviews, thus contribute towards auditing Phase One outcome, the author decided to skip traditional coding process before interpreting the quotes into trust statements or augments.

Notedly, trust codes through both Phases are based on the same five determinants generated through literature analysis from Conceptual Background Chapter. Hence the five proposed determinants along with five propositions will continue being the focal analytical points for the Results Chapter. However new discovered trust factor outside of these five trust determinants will also be demonstrated at the last section of next chapter.

RESULTS

As disclosed above, five determinants survive through empirical research stage with critical examination of the grounded theory at Phase One and interpretive analysis at Phase Two. Before meticulous demonstration, an overall analytical result is depicted as below in Table 2.

Trust Determinants	**Grounded Advocates**	**Grounded Oppositions**	**Academic Blockchain Expert Advocate (Y/N)**	**Professional Blockchain Expert Advocate (Y/N)**	**ETS Experts Advocate (Y/N)**
Situational normality trust	2 (interface) 1(functional)	0	Y	N	Y
Structural assurance trust	12	4	Y	Y (very strongly)	Y (very strongly)
Peer-based trust	22	1	Y (strongly)	Y	N
Knowledge-based familiarity trust	2	0	Y (very strongly)	Y (strongly)	Y
Control-based trust	39	0	Y	Y (strongly)	Y (strongly)
Ethical trust*	5	0	N	Y (proposer)	Y

**New determinant proposed by interviewer*

TABLE 2 RESEARCH RESULT OVERVIEW

4.1 PROPOSITION ONE

Situational normality as an important factor in reaching trust while applying blockchain to ETS?

Situational normality trust, albeit influential to an extent, is not considered a significant type of trust for blockchain application in setting of ETS.

The concept of situational trust derived from our literature is described into two aspects: application interface appears trustworthy; basic functionalities work out as expected. According to the empirical reports, functional normality enhances the trust in applying blockchain because of the guarantee of smart contract. Direct quotes such as, “Prosumers have blockchain-level guarantee that the support policy will execute exactly as coded in the smart contract”, “Smart contracts provide reliability that the code will always execute exactly as written” (Mihaylov et al., 2018) display that functional normality is mostly taken for granted rather than deterministic, because inevitably a baseline of any user trusting and adopting new application would be functioning as expected. Although it is worth of attention that if this trust is based on smart contract when applying blockchain, backbone may consider to be the procedures being trusted, which is more towards control-based trust. Hence both quotes mentioned were grounded for both situational trust as well as control-based trust.

Both interviewed blockchain experts recognised the necessity for users to perceive their desired functions being achieved before they could trust an application, which also applies to blockchain application. But neither expert considers functional normality as a major trust influencer.

Regarding trust in application interface, Fuessler et al. (2021) recognises its influence on blockchain application trust. But this influence was strengthened by the Finnish ETS experts who regarded current EU ETS being trusted by the users partially because the carbon market interfaces are similar to normal online banking application interfaces, "For example, Finnish banks, where you can see your account and make transactions and such, it's probably very private, of course, no one else can see your stuff at the bank". Thus, application interface trust should not be neglected when applying blockchain to EU ETS, even though it has not been substantially backed up.

4.2 PROPOSITION TWO

Structural assurance as an important factor in reaching trust of applying blockchain to ETS?

Structural assurance is confirmed to be a key determinant of achieving trust in applying blockchain to ETS in Finland.

The concept of structural assurance trust is defined as third-party guarantee while applying blockchain, instead of trust in technological structure and procedures, which in this research is categorised as control-based trust. This conceptual difference is rather vital for our research because the notion of adopting blockchain is getting rid of the need of third-party trust, whereas in the context of CO_2 emission trading, trusting the authority has so far been absolutely dominate. Findings of this qualitative research have corroborated this. The most typical example of this trust originates from the belief that legal framework should be developed to provide "factual" guarantee for blockchain application. Direct quotes being "A legal framework regulating key aspects of blockchains such as digital identification of participants (humans and machines) and 'signatures', legal enforcement of smart contracts and the legality of crypto currencies can help to engender trust of blockchain technologies among government entities and businesses" (Fuessler et al., 2018), "Ensuring that individuals can provide legitimate proofs of identity such as government-issued passports or driver's licenses is a common practice towards building a legal and trustworthy ecosystem in the Blockchain space" (Braden, 2019a), both display users' trust in some form of legal assurance should enhance their trust in applying blockchain.

Besides legal system, another element of this trust is discovered even more critical: a trust in authorised or governmental entities. Braden (2019b), much similar to the academic frameworks illustrated at Conceptual Background chapter, argued blockchain emission tracking system should be integrated into the current national registry systems to secure higher trust, "A blockchain registry jointly run by countries pursuing voluntary cooperation under Article 6 of the Paris Agreement would ensure that every outcome generated, issued and internationally transferred is coded into the blockchain and reconciled with national registries. Such a network would have to be run by computers associated to the Parties that cooperate accordingly".

The entity that provides this assurance trust is not restricted to be national level, but also global level as Fuessler et al. (2021) stated "At that stage, the pros and cons of blockchain/DLT based systems should be carefully reassessed against conventional database solution where trust is less based on (blockchain/ DLT) technology but on the institutional level (e.g. similar to the existing UNFCCC CDM registry)". As referred at the Introduction chapter, UNFCCC represents United Nations Framework Convention of Climate Change. CDM registry was established by UNFCCC in 2005 when the initiative of implementing carbon dioxide emission trading approach was introduced globally (UNFCCC, 2022). Hybrid effort between national authority and global institution can also strengthen this structural assurance for blockchain application trust, for instance "Panda Green Energy entrusted the New Energy Exchange to develop a smart power station blockchain management system and Pandacoin. Pandacoin is a digital currency that uses the Panda Power Station jointly built by the Chinese government and the United Nations as an asset carrier" (Wu & Tran, 2018) can be a good example.

Not surprisingly, professional blockchain expert, from a certification body under United Nations that enables CDM, also strongly resonated with this global level of structural assurance trust as a crucial factor in blockchain application trust for emission trading. He argued that structural assurance in a pivotal position within emission trading scheme. The current blockchain used for ETS is mostly permissioned or private, in Gold Standard's case tokenisation, in which "Structure and assurance is a big deal, since if you're part of an emissions trading system, you want to know that the system you're using is acknowledged and legitimate within the trading system”. He continued, “Or if you want to tokenize or buy a gold standard credit, that's been tokenized by somebody else, you're gonna want to know that gold standard stood by that as well, that is actually a gold standard credit”. The professional expert also disclosed the fact that numerous blockchain start-ups proactively asked for “Gold Standard’s endorsement for their approaches. So, we get twice a week probably, at the moment, coming to us and saying we've got this thing with gold standard, be interested in partnering”. These start-ups most likely aimed to promote themselves as recognised or proved by Gold Standard. Since the standard body operates under UN, it is a strong argument to consider structural assurance trust rather crucial in blockchain trust in ETS.

Moreover, the ETS experts from Finnish Energy Authority confirmed the significance of structural assurance trust in EU ETS deeply as well. For instance, they stated “If there are very unorthodox incidents during the transactions, of course, banks use the funds have all the KYC (Know Your Customer) stuff. We must know our customers”. KYC represents a set of processes verifying identities and behaviours of the users at the financial sector anti-laundering diligence. It is embedded in EU ETS and being implemented since 2015 (European Court of Auditors, 2015). Meanwhile, they asserted that the government is able to verify the allowance transactions in case untrust behaviour appear. Also, the emission trading entities are allowed to appeal onto European Commission if they consider the free allowances unfairly allocated against them. The clear statements together have formed strong attitude of supporting structural assurance trust as a significant trust determinant for ETS.

Additionally, the academic blockchain expert also regarded this trust highly but from a slightly different perspective, “The utilities probably are backing up the initiative. Because in the case of energy system, they still must ensure that people will receive electricity without any problem with the delivery of electricity. So probably, that's kind of a level of assurance that they were willing to provide”. Based on empirical experiences of the expert, due to credibility of the utilities, backbone of NRGCoin project, trust in adoption should be heightened. Even though he clearly does not acknowledge this type of trust as a key determinant.

Nevertheless, four quotes from two empirical papers are grounded against the significance of structural assurance trust. Within which “In this way prosumers need not trust any organization or institution for their green energy award payment, as they can rely on the guarantees of Blockchain technology itself” (Mihaylov et al., 2018), “Multi-signature technology, blockchain, and anonymous information flow in distributed energy transactions, and proposes a solution to ensure transaction security when third parties are not trusted in a distributed smart grid" (Wu & Tran, 2018), display that third-party trust should not be needed if blockchain is applied properly. Meanwhile "What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party" (Wu & Tran, 2018) emphasises instead of structural assurance trust, the control-based trust defined in this research is a determinant of trusting blockchain application.

Despite these 4 grounded oppositions, considering rather strong advocates received from professional blockchain expert and ETS experts, structural assurance trust should still be regarded deterministic for blockchain application trust.

4.3 PROPOSITION THREE

Trust between unacquainted peers as an important factor in reaching trust of applying blockchain to ETS?

Peer-based trust, especially when peers somewhat acquainted, is influential in blockchain application trust, but not particularly when applying to ETS.

Even though Proposition 3 derived from the trust literature at our Conceptual Background emphasises on trust between stranger peers in a business network that others would not behave arbitrarily to sabotage business transactions. It is technically hard to delineate the level of acquaintance between peers in a network in qualitative research, because it is not quantitative research which might send surveys to considerable amount of blockchain participants. Also, the composition of peers in a blockchain application network can be rather sophisticated, it is complicated to verify their acquaintance with each other. Except for unusual case such as "Blockchain participants append information to a decentralized immutable database, where those participants are either not known or not trusted, and where the system does not rely on central third parties" (Mihaylov et al., 2018), which specifically points out unfamiliarity between the peers.

Moreover, it may consider common sense that no matter how acquaint peers are, the common objective of any participant joining and staying in a business network should be to gain profits for oneself. Hence grounded theory approach conducted on the selected empirical papers did not differentiate relevant peer-based trust points by acquaintances.

Supporting arguments of peer-based trust as an influential indicator of blockchain application trust, albeit not evenly, can be subtracted amongst all eight empirical papers. Some of the direct references being, "Blockchain technology brings trust to peer-to-peer transactions–particularly important in the context of weak regulatory settings or under decentralised governance" (Fuessler et al., 2018), "Not only does the smart contract reduce the administrative costs associated with fulfilling such policies, but – due to the distributed nature of the smart contracts on the blockchain – all stakeholders and regulatory bodies trust in the transparency of the process" (Braden, 2019a), " Such smart contracts are immutably integrated in the fabric of the blockchain/DLT and may therefore provide an additional layer of trust to the parties in a purchase agreement"(Fuessler et al., 2021).

Otherwise through indirect manner, "Its most important contribution lies probably in the ability of blockchain-based systems to create new levels of trust that allow far greater integration of the private sector, where integration among private entities implies peer-trust; "Blockchain solutions are the building blocks of trusted cooperative platforms that can help incentivise and track climate action by a broad range of climate actors—from private sector players through to individual citizens", which indicates blockchain application makes platforms being trusted, because it enhances the trust between private companies and between individual persons" (Fuessler et al., 2018). "Moreover, #REDD-Chain Project may increase transparency and trust through benchmarkable outcomes and incentive mechanisms that open up access to new kinds of financing and lower transaction costs", in which trust in benchmarking obviously reflects peer-based as well (Braden, 2019b); "B-ETS creates an account for the emissions generated from each vehicle and allows exchanges among vehicles in a trusted manner based on blockchain and smart contracts (Nguyen et al., 2021)", where all vehicles are evidently peers of the blockchain application.

In numerous contexts the significance of peer-based trust are outstood from a negative perspective, "Stakeholders do not trust each other given diverging incentives", "Especially relevant in the context of supply chains where suppliers may not necessarily trust each other but are required to share data" (Fuessler et al., 2018), "Smart contracts are deterministic exchange mechanisms controlled by digital means that can carry out the direct transaction of value between untrusted agents"(Braden, 2019a), "Insurance payments can take months to process, which forces farmers into poverty after climate disasters even if their crop was insured. This has naturally eroded trust among those farmers. Blockchain technology can automate the lifecycle of the insurance product and thus reduce costs by up to 41%, according to a study conducted by ACRE and Etherisc with the Global Innovation Lab for Climate Finance in 2019" (Guyer et al., 2021), "For example, because the Energy Internet has many participating nodes, the trust problem of distributed decision-making can be the key issue, while the blockchain technology solves exactly the trust problem of the centreless decision-making organization” (Wu & Tran, 2018).

Despite all the listed advocates, Wu and Tran (2018) sings a different tune by stating that “The blockchain system uses trusted mathematical algorithms to regulate the behavior of transactions. The data exchange between nodes in the system does not require mutual trust. The operating rules are open and transparent”, which clearly defies necessity of peer-based trust because only algorithm of the blockchain application needs to be trusted.

The academic blockchain expert also believed in the impact of peer normality trust on blockchain application, but particularly pointed out significance of this trust when the peers in the network are somehow acquainted, “Under a network of this, peer- based trust, I think it is more like in social media and social platforms is the network effects are like you see other peers joining the technology and using the technology, and then therefore you are also kind of influenced and then you trust the system”. The context of his opinion is that NRGCoin was operated amongst a small group of prosumers who could share their opinions about the blockchain application, in this case the peers were more like neighbours even if not knowing each other personally. These peers should have more inherent beliefs in behavioural normality of each other, compared to blockchain projects with much more participants involved.

On another hand, professional blockchain expert also recognised the impact of peer-based trust as Gold Standard working alongside International Emissions Trading Authority (IETA), which is “A membership body of the big participants in emissions trading schemes”, which is “a good forum for these large carbon emitters to build peer-based trust”. IETA published a new paper in March 2022 “Digital Climate Markets” where the group displayed their determined plan of implementing carbon credit tokenisation for future emission trading. Therefore, this peer-based trust evidence is indeed relevant to our research topic, although as professional expert asserted, it is not an important trust for blockchain application.

ETS experts neither particularly confirmed importance of this type of trust in emission trading nor denied the potential importance though. Therefore, although peer-based trust is considered an influential indicator of achieving blockchain application trust, it cannot be verified applicable towards the setting of emission trading.

4.4 PROPOSITION FOUR

Knowledge-based familiarity as an important factor in reaching trust of applying blockchain to ETS?

Knowledge-based familiarity trust is confirmed to be a key determinant of achieving trust in applying blockchain to ETS, albeit less important particularly to Finland.

It is important to restate that this familiarity trust to be knowledge-based because the author encountered confusions from the experts during the interviews between this trust and situational normality trust. Situational normality emphasises on the perceived normality of application interface or functionality which can be judged by user's experiences of familiar applications but unnecessarily with knowledgeable understanding of the application or the technology behind the application, which knowledge-based familiarity concerns. It is particularly relevant due to the fact that blockchain knowledge is yet to be globally spread as described multiple times above by this research (see also Section 1.3).

Even though knowledge-based trust should logically be a large influencer to the trust in novel technological practices (see also Section 2.4) and blockchain application is a typical example of them, especially at ETS setting. There is only one quote out of all chosen empirical papers indirectly supporting the importance of this trust factor, "Therefore, some jurisdictions allow for regulatory 'sandboxes' that allow for experimentation with blockchain approaches in different sectors within a supervised environment with trusted business partners" (Fuessler et al., 2018). Acquiring knowledge via training in advance clearly demonstrates how significant knowledge-based trust is for user's trust in adopting blockchain. One of the reasons this trust almost not being mentioned in these papers can be the fact that, authors of these papers are almost always experts with prior knowledge of blockchain application and/or emission trading. Thus, they may not have conducted investigations to compare users' trusts with and without previous technological understandings.

Nevertheless, both blockchain experts regard knowledge-based familiarity trust as crucial factor in reaching trust while applying blockchain. Starting with the academic expert, from his substantive NRGcoin practice, he reckons that knowledge-based familiarity trust came as the initial trust in adopting the blockchain experiment before other trusts emerged at latter stages, one of his quotes being, "Because they know all about the technology so they understand what can be done what cannot be done and they say okay, (in the case that we are talking for instance the energy or whatever) I think it can be solved with this technology". He further emphasised on the importance of having a few "prophets" with knowledge-based familiarity within the user group, who would then diffuse relevant knowledge and trust amongst other members in the network, "The people that come for the cooperative, but usually there are two or three that are kind of leading all the actions and new action within the cooperative. And those two or three, probably they know a lot about information technology, they know a lot of our electricity systems, and they are the ones like advising the whole cooperative like yeah, this could work, we should explore this option or something like that". Hence the academic expert considers knowledge-based familiarity trust can be a key trust determinant when at least some members in the user group have prior technological understanding of the blockchain application and trust in it.

Professional blockchain expert did not particularly emphasise on the importance of having knowledge leaders in a user group, but he did highlight the significance of diffusing knowledge of the technology and application amongst all relevant stakeholder groups of sustainable projects including emission trading tokenisation projects. To support his point of view, he showcased two actions Gold Standard have been operating, one case is being an initiator and advisor for IETA, where the expert and his colleagues form work groups to promote the knowledge of carbon tokenisation towards members of IETA, some of the largest CO_2 emitters of the world. The second case is called Digitising MRV, also a project specifically serving to diffuse knowledge of carbon credit, tokenisation for emission trading, "Some work groups at the moment on the use of blockchain, digitising MRV. It is all about increasing the knowledge of the organization, and then using the organization to kind of reflect back outwards what we think the key issues are". Obviously, it is due to the significance of knowledge-based familiarity trust in blockchain application to ETS, that Gold Standard, a certification body under UN, have been dedicating such efforts in enhancing this trust.

Even though not confirming directly, the ETS experts echoed with the influence of knowledge-based trust indirectly, "Especially for big companies, it is very easy for them to participate, they can compete with each other. So, they can use some sort of traders some or even go to big markets where, where the auctions are made, or there is a trading with the allowances". The fact that large carbon emitters in Finland nearly always conduct their emission trading via trading experts, indicates ETS participants do regard knowledge-based familiarity highly since they trust these traders only because of their expertise of carbon trading. Logically they would regard this trust even higher should blockchain be applied to emission trading.

4.5 PROPOSITION FIVE

Control-based trust as an important factor in reaching trust of applying blockchain to ETS?

Control-based trust is confirmed to be a key determinant of achieving trust in applying blockchain to ETS in Finland.

Clarifying the concept of control-based trust was proven necessary because it could be confused with Proposition Two at some moments of during interviews. Defined from the literature at Conceptual Background chapter, control-based trust focuses on users' trust in procedures provided by the technology such as technology-based structures, mechanisms, protocols. Hence compared to the 3rd-party guarantee emphasised at Structural Assurance trust, control-based trust is more of an internal trust that users feel themselves in control via adopting blockchain technology and gaining the benefits of transparency, decentralisation, and automation, without any need of external security measures of authorities.

With a clarified definition, the author has grounded advocates for control-based trust factor from all eight empirical reports. For instance, as responses to overcome current MRV shortcomings with blockchain, Fuessler et al. (2018) argue that "Transparency brought by blockchain can help increase trust in the quality of the data by making it simple to establish the origin of data and how it has been collected and verified"; "Blockchain alongside other technologies can achieve higher trust and integrity thanks to automated systems for collection, recording and cross-checking". Also Braden (2019b) argue "By leveraging diverse data sources and putting them to work, RCP will enable actionable projects with trusted, automatable processes, including performance-based payments". Meanwhile smart contract has increased blockchain application trust via enhancing MRV efficiency, "Not only does the smart contract reduce the administrative costs associated with fulfilling such policies, but – due to the distributed nature of the smart contracts on the Blockchain – all stakeholders and regulatory bodies trust in the transparency of the process" (Braden, 2019a).

As referred briefly at Introduction and Conceptual Background chapters, a combination of blockchain and IoT has proven trustworthy at various empirical cases. For instance, referring project of automating water meter project with blockchain in Kenya, "Applying blockchain technology to the monitoring system will be highly beneficial in ensuring that consumers can track their data and are billed accurately based on what is collected by the smart metre, thereby increasing trust", "Higher trust levels due to greater transparency of distributed system – with tax and dividend transactions being publicly visible/traceable; particularly relevant in countries with weaker regulatory frameworks"(Fuessler et al., 2018). On another hand, analysing the project of Etherisc enabling crop insurance with blockchain for Kenyan farmers, "The immutable nature of blockchain applications can generate increased transparency and trust for its users. This has been observed in the Etherisc crop insurance use case in Kenya, where blockchain technologies automate the lifecycle of the insurance product and thus reduce costs and increase confidence in the database"; "There is also a full audit trail with all details of the blockchain, providing a higher level of transparency than with regular digitalisation. These features eliminate trust issues on the farmer's side, and therefore remove one major obstacle to mass adoption" (Guyer et al., 2021).

Zooming out from Africa, blockchain application trust sources are found in South America. For example, an empirical case in Brazil has seen evidence of control-based trust, "Brazilian Development Bank established a Memorandum of Understanding with German Development Bank in February 2018, allowing it to use and collaborate on the improvement of Germany's Blockchain-based workflow management tool called TruBudget. The tool allows for the real-time sharing of information between Brazilian Development Bank and the donor side with high levels of trust" (Braden, 2019b). On the other hand, a more relevant application named Green Tracker adopted in Chile for tracing GHG and improving MRV which "Allows users to build trust and confidence in their environmental performance, claims and/ or environmental assets that may be created throughout our solution"; it also "enables users to trust the data that has been stored on our databases, because it can be proven that the data has not been tampered with, corrupted or modified" (Guyer et al., 2021).

Adjusting focus towards another continent, from a blockchain application project again combined with IoT in India, Guyer et al. (2021) found that "Cooking data received from the IoT platform will be written into a blockchain, providing a real-time carbon inventory. Blockchain will make the entire process accountable. Impact buyers can trust the data source, and also make sure that the money is transferred directly to the impact generator. The process shortens the payment period compared with the traditional approach to climate financing."

Based on blockchain application cases in developing countries including some illustrated above, Fuessler et al. (2021) argued that "The use of blockchain technologies/ DLT and digitized MRV is particularly rewarding for countries where the governmental systems tend to be rather weak and trust in data needs to be built", "They include increased security, as blockchain/DLT entries are immutable and therefore provide for additional trust, which may be particularly important in the context of countries with weaker institutional capacities and governance settings".

Academic papers also agree on the significance of control-based trust for blockchain application. Some grounded quotes being, "Instead, the procedural rules in the blockchain are used to give each other trust", "The reason is that it can establish reliable trust between nodes in the network, making the value transfer process independent of the central node. The addition or update of network data is accomplished by a distributed node consensus algorithm, which is transparent and can protect privacy" (Wu & Tran, 2018). Also, from the empirical study of tracing carbon emission between vehicles, Nguyen et al. (2021) confirmed strongly that smart contract plays a critical role in reaching blockchain application trust, "The execution of the smart contract guarantees trust among vehicles and driving habits, (e.g, avoid idling, speeding, etc) and CO2 levels", "Based on the autonomous execution of smart contracts, the incentive mechanism is guaranteed to work in a trusted and distributed manner", "The vehicles can exchange their emission allowances through autonomous smart contracts in a trusted manner".

Compared to Proposition Two where profound amount of support was also grounded from archival study, the blockchain experts have a bit surprisingly not given strong approval for control-based trust, even though both recognise the trust in the protocol procedures as a basis of gaining users' adoption trust.

Nevertheless, the professional expert had offered a precious example that control-based trust could be lost when certain blockchain mechanism is manipulated and become untrusted, "When Klima Dao which we looked at. Also token protocol it was they first started, they were retiring VCs credits and then issuing a token, but that is a breach of governance because retirement means end of use. That is what has been claimed you can't use it for anything else if it continues to be traded after retirement, okay, it's double counting. So that control that that disconnect between the two worlds is a real control issue for us because it breaches governance". Klima Dao, created in 2019, is a "de-central" bank with monetary policy of a new carbon-reference token named Klima (Klima DAO, 2022). In spite of the doubt about their double counting issue, the crypto is being traded today and claim to contribute towards CO_2 emission. It is not a concern of this research if certain blockchain application is trustworthy or not, but this concern does heighten the significance of control-based trust.

To interpret the opinions of ETS experts, control-based trust is generalised to emission trading stakeholders' trust particularly in the procedures of current ETS that they feel themselves in control, which can be backed up by structural assurance, but does not lower its supporting value. Their quotes advocate control-based trust may include, "And it is possible to (trust) because the rules are same for everyone", "It is always a possibility that someone is fraudulent or at some other way. So, the idea is that because you know that someone who you are transferring allowances or transferring allowances to you has always gone through the same kind of procedures", "where there's different difference of opinion about for example, how much some company gets allowances or how they trade, but the system itself contains the possibility for a company to appeal on decision". All these quotes reflect that ETS experts' rather strong support to the importance of control-based trust in any technological application to emission trading.

4.6 ANOTHER PROPOSED TRUST DETERMINANT

New proposition: Ethical trust as an important factor in achieving trust when applying blockchain to ETS?

Ethics-based trust can be influential to blockchain application trust in certain countries' ETSs, but in Finland and not deterministic.

There is currently no scientific or academic definition for ethical trust since ethic is a concept with wide explanations. The author interpreted this potential trust determinant as "*ethical trust*" based on the proposer himself professional blockchain expert who first named it, "equitable access trust" during the interview by asking, "Could everybody in our portfolio or the communities we are trying to reach use it (blockchain technology) based on their capacity and understanding? Do we leave anybody behind?"; "Are there people in the world that could not use this technology right now, because of capacity or access issues? How do we make sure that if we flip our system over to this that we do not accidentally leave somebody behind?". He suggested that if a technology is believed to be ethical, it should presumably be more trusted by users or potential users.

A practical example of this trust he raised, "A women's group in Borneo, for example. I do not think that they can really access the carbon markets without the consultant even now. So, I don't think blockchain can fix that on its own obviously, but we don't want to make it even harder for them to be able to do that". He indicated that if a blockchain application could enhance the fairness of accessing carbon market among more people groups globally, these groups of people should naturally trust that application for carbon trading. "We won't trust this unless we show we've got a system that doesn't leave anybody behind. It does not end up causing more environmental damage than it was worth," the expert further asserted.

The author interpreted his holistic explanation of this proposed trust concerns of all three sustainability pillars: social, economic, and environmental (Purvis et al., 2019). Meanwhile the trust would concern two relations of "sustainability ethics" defined by Becker (2012): the moral relationship between humans and future generations; the moral relationship between humans and nature. Therefore, *ethical trust* is the name generated based on all above and will be referred to as this trust factor proposed by the professional expert.

With a more clarified definition, five quotes from 3 empirical reports are dedicated towards the impact of ethical trust on blockchain application, for instance Fuessler et al. (2018) argue “Blockchain is also a potential game changer in countries with weaker governments, as it may replace some potentially corruptible and fallible governmental processes and institutions by a decentralised yet trusted technological tool”, an ethical trust example of blockchain usage for Kenyan farmers referred at Proposition Five Section, “Insurance payments can take months to process, which forces farmers into poverty after climate disasters even if their crop was insured. This has naturally eroded trust among those farmers. Blockchain technology can automate the lifecycle of the insurance product and thus reduce costs by up to 41%, according to a study conducted by ACRE and Etherisc with the Global Innovation Lab for Climate Finance in 2019”(Guyer et al., 2021). With Fuessler et al. (2021) restated that “The use of blockchain technologies/ DLT and digitized MRV is particularly rewarding for countries where the governmental systems tend to be rather weak and trust in data needs to be built”.

Not to forget, the Klima DAO double counting concern of the professional blockchain expert described in Proposition Five (see also Section 4.5) also back proves the importance of ethical trust. The whole objective of MRV embedded in ETS especially with assistance of blockchain technology is to avoid double counting the CO_2 abatement, if it is infiltrated and manipulated not achieving the primary goal, stakeholders’ trust in carbon tokenisation can be significantly tarnished. Because it would exacerbate carbon emission and become sustainably unethical.

Even though not being emphasised, influence of ethical trust was also mentioned by ETS experts, “And I guess in Finland, it is very common to trust authorities, not just Energy Authority, but everyone, also internal peers. But I suppose I could see that in some European countries, citizens would enjoy if there's a moral process; it would be more transparent that anyone could see the calculation himself and check if it makes sense, or not”.

Since predominate cases of ethical trust examples taken place in developing countries and ETS experts emphasised it may not be needed in Finland’s case, the influence of ethical trust in blockchain application trust should only be outstanding in certain areas of the world.

4.7 PROPOSED TRUST MODELS

Even though not all the proposed key trust factors verified to be deterministic according to the empirical papers and expertise of experts, most of them however are approved to be critical to the beliefs in applying blockchain. Most proofs from the experts have already displayed at the previous sections, but extra mile further from those mentioned, both blockchain experts proposed their trust patterns respectively with some trust determinants they agreed on.

SEQUENTIAL MODEL

The academic blockchain expert proposed trust sequence he observed from NRGCoin project, which the author interpreted as sequential trust model as below.

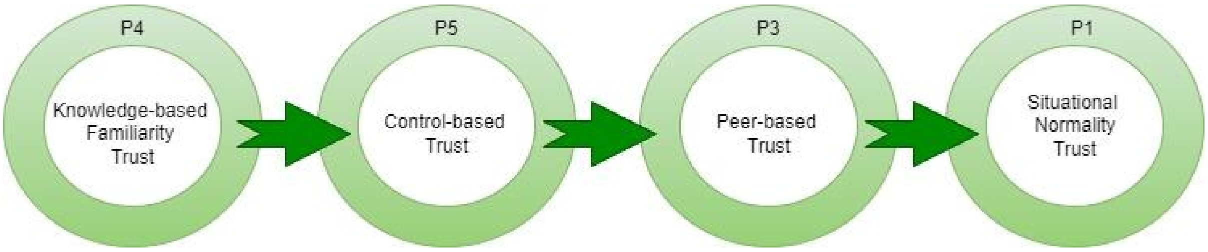


FIGURE 4 SEQUENTIAL TRUST MODEL FOR BLOCKCHAIN APPLICATION

As illustrated above at Proposition Four (see also Section 4.4), the academic expert holds high regards to knowledge-based familiarity by considering this type of trust as the trigger for the other three trust factors subsequently. He observed that certain number of the user group members who have been acquainted with the blockchain application would easily trust the practice prior to the implementation, because they “understand what can be done what cannot be done”, “(they) think it (the energy tracking problem) can be solved with this technology”. Following which, the expert added, “Then the structural assurance (he meant control-based), because again, they kind of know what are going to be the rules of the game. And then everybody is going to follow those rules ideally. So, they say, okay, then I trust that we can use this”. Here the trust in undergoing the same procedures brought by technology, should be categorised as control-based because he never mentioned the role of third-party guarantee that engenders this trust.

Then the expert continued, “Then in the third proposition the peer-based is also they see who are going to be joining the network, right. They see, these organizations are joining, these others are also joining. So, I trust them. So, I think, yeah, we can do business together, right, and join the network”. Echoed with what was described in Proposition Three (see also Section 4.3), when the users are somewhat acquainted with each other, the initial trust in the blockchain application amongst the prophets, would spread among the peer users.

After peer-based trust, almost instantly situational normality trust is built according to the academic expert, “Maybe immediately after them is this situational normality, because then they see the system operating. And then they see okay, yeah, it is achieving what we are trying to", that matches definition of functional normality trust.

PYRAMID MODEL

On another hand, the professional blockchain expert considered only 3 proposed trust factors deterministic, with which he suggested a rather different pattern of relations between these verified determinants.

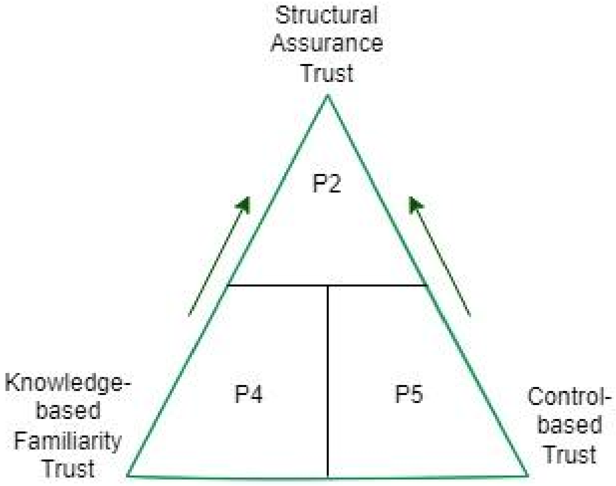


FIGURE 5 PYRAMID TRUST MODEL FOR BLOCKCHAIN APPLICATION

Compared to the sequential model, which is horizontal and flat, this pyramid trust model proposed by the professional expert has hierarchy, although simply one layer. Based on his expertise in carbon tokenisation for private sector usage, the expert, employed under UN standard entity, would place structural assurance as the pyramidon above any other trust factors undoubtedly. "I think structure and assurance is a big deal in our space. So, if you're part of an emissions trading system, you want to know that the system you're using is acknowledged and legitimate within the trading system, right. Or if you want to tokenize or buy a Gold Standard credit, that's been tokenised by somebody else, you're going to want to know that Gold Standard stood by that as well, that is actually a Gold Standard credit", "It seems to me, structure assurance within the schemes that exist, is the kind of pivotal moment and then to get to that place". Herewith, the prioritised importance of structural assurance trust cannot be accentuated more.

He also asserted certain influence of ethical trust on structural assurance trust, "But to me, the unique thing about emissions trading and carbon trading is that it has to work right. It's not just a profit-making thing. We actually have to try and save the world with this stuff. So, it does need that kind of structure assurance, I think because otherwise you're You'll get heavily scrutinized for it. So yeah, that's why I think P2 is so important to the main uptake of". But the author did not append ethical trust to the Pyramid Trust Model because ethical trust defined at the last section (see also Section 4.6) emphasises on the human-sustainable trust, but "save the world" is too general to be classified into this trust aspect.

Then the professional expert continued suggesting the foundation of reaching structural assurance trust, "So, for schemes like mine, to be able to give that structure assurance, my feeling is that it's a combination of the bottom two, P four and P five, on the basis that we need to get used to it", "So I feel like in terms of I fit into a running order, I think P two is necessary for it to really, really grow so that people know they're using it right. And then for us to be able to do that p four P five become the critical ones". Following expert's suggestion, the author interpreted knowledge-based familiarity as the left leg of the foundation whilst control-based trust as the right leg, as displayed at Figure 5.

Regarding the left leg of foundation, the professional expert added, "We need to upscale and understand better than we do right now, to be honest", which he referred to upscaling the knowledge diffusion of using blockchain; in the case of Gold Standard, of adopting carbon tokenisation. Examples include their project of Digitising MRV and assigning study groups to IETA, which were meticulously described at Proposition Four (see also Section 4.4).

Concerning the right leg, "Then we need to be assured ourselves that the control that's needed for our governance is in and controlling things like emissions of the actual system itself is under control, that kind of stuff", herewith he highlighted blockchain regulator like Gold Standard should ensure the blockchain application provided is actually being transparent, functioning according to embedded mechanism. Within the definition of our research, this application trust is more of a joint-trust between structural assurance trust and control-based trust rather than solely control-based.

Important to be noted, although professional blockchain expert depicted knowledge-based familiarity and control-based trust as the base for structural assurance trust, he referred these two trusts acting more as enablers of structural trust but not as necessities.

DISCUSSION

The objective of this qualitative research was to explore the most critical trust factors in applying blockchain to emission trading in Finland. The existing problem was introduced at the first chapter in terms of why blockchain technology should be used for emission trading and what the main challenges are. Afterwards at the second chapter, profound amount of credible literature was utilised to define blockchain technology, ETS, how blockchain has been applied to emission trading before analysing and proposing the potential trust determinants of blockchain application to ETS in Finland. The empirical part of this research was divided into two phases: external archival study on 8 papers and semi-structured interviews with 4 experts. After which, two analytical approaches were adopted respectively: grounded theory and interpretative analysis. As for results, 3 proposed trust factors confirmed to be the most critical, and two trust models were formulated based on interpretations from the blockchain experts.

5.1 NO TRUST NEEDED?

One point worth being discussed is whether trust is "needed" while applying blockchain to emission trading in Finland. Although trust is commonly considered as a prerequisite of any kind of business transaction because business actors need to have sufficient beliefs that the other trading parties would behave benevolently before they agree on trading with each other (Pavlou & Gefen, 2004). Thus, theoretically if there is no trust there should not be any business transaction. Inevitably, emission trading is part of business transaction behaviour that various stakeholders should supposedly need to trust each other.

However, there may be countries where emission trading trust is much less noticeable, as the interviewed Finnish ETS experts said, "I think regarding the free allowances, I don't think anybody is trusted. I mean, that we don't as a government give out the free allowances, the EU Commission goes through every calculation. So no, no country has the power to decide how much they want to give out to their own installations". Although they said, "No trust is needed", in the setting of our research, this quote can be interpreted as: no other type of trust is needed when there is strong enough structural-assurance trust in participating in emission trading.

Meanwhile these ETS experts appended that they would understand citizens other European countries might want higher transparency of how carbon allowances allocated and other procedures of emission trading (see also Section 4.6). This can be interpreted as: in countries where structural assurance trust is not strong, there should be other kinds of trust. This gap can be filled by adopting blockchain technology, the reasons were demonstrated in detail at the Introduction Chapter (see also Section 1.3).

Rather unsurprisingly, one empirical paper selected for our archival study confirmed this strong structure-assurance trust existed at Finland's Nordic neighbour Sweden (Fuessler et al., 2021). One of the major conclusions of this paper is, "If SEA (Swedish Energy Authority) wants to implement the registry system focusing purely on its domestic needs, then a conventional database may be a better solution. Such a system may be locally efficient and, in a domestic system for Sweden, public trust in government and public databases is high enough that there is no need for a technological trust layer trough blockchain/DLT". Whereas Fuessler et al. (2021) did emphasize blockchain application should award ETSs of weaker countries with higher trust in emission trading processes, probably along with ethical trust enhanced (see also Section 4.6).

Interestingly, the professional blockchain expert also shared a similar claim of trust not "needed" from a different perspective, "Because different organizations, you know, sometimes the private sector, particularly the entrepreneurial private sector, does not necessarily need to trust to use it, like the risk is almost getting on board before everybody is mainstream". Herewith the expert's "trust not needed" can be interpreted as: if an application has been proven trustworthy, other trust is not required before users adopt. However how can an application be trustworthy in the first place? Actually, the author considers he implied that: once a blockchain application is approved by Gold Standard, users may not need other type of trust to use the application. Because they trust Gold Standard, to a certain extent, as a blockchain representative under UN authority. Therefore, once again, similar to the "trust-not-needed" notion of the ETS experts, when there is strong enough structural-assurance trust, no other type of trust is needed to adopt blockchain application.

Nevertheless, the professional expert suggested another potential factor for this "trust-not-needed" scenario, "And we definitely see a lot of that in the carbon markets. There's a lot of startups, for example, that have thrown their lot in with blockchain and tokenization. Not based on holistic, shared, participatory trust of the entire market that's based on we find get there first, everybody else will catch up, and then I'll have an advantage". With this quote, he might indicate for another type of trust that related to blockchain application to emission trading as "economic benefit trust". When the belief in economic reward is strong enough, any other trust element can be downplayed. This is more linked to the financial aspect of blockchain because crypto products are highly volatile which many investors gamble on.

However, emission trading or carbon tokenisation is much more than a financial market, as the professional expert asserted “we are actually trying to save the world here”. He emphasised that ethical trust based on strong structural-assurance trust should always prioritise above economic benefit (see also Section 4.6). Hence, even when economic benefit seems prevailing for companies, in terms of emission trading with blockchain technology, economic-benefit trust can only be an indirect influencer exists on a solid basis of structural assurance trust.

5.2 RESPONSES TO THE CHALLENGES

As point by point illustrated at the Introduction Chapter, there have been four main challenges of blockchain application towards emission trading, which have impeded the trust of blockchain being adopted for sustainable objectives (see also Section 1.4). Even though they were answered respectively, but only in a rather brief manner. Whether this research is able to provide further responses to these challenges, remains a subject of discussion.

First challenge of energy consumption via blockchain application had actually not been mentioned by any expert, neither has it been depicted as a major issue related to trust in blockchain application amongst the selected archival papers. The predominate reason should be that to a foreseeable future, the form of blockchain being applied to emission trading should be permissioned or private, as the professional blockchain expert referred multiple times regarding carbon tokenisation. Moreover, as delineated by the ETS experts, currently only the largest CO_2 emitters are concerned of trading carbon allowances, but as an advisor of IETA (with members of largest carbon emitters over the world), the professional expert did not disclose any energy-consumption concern. Moreover, the largest blockchain application platform, Ethereum confirmed their nearing the merger phase from PoW to PoS on 14th July 2022 and announced the merger should be finished in September 2022, even though without a hard deadline (Jha, 2022). The founder of Ethereum Vitalik Buterin argued this transition can “ultimately reduce the chain’s energy consumption by upwards of 10,000x” (Thurman, 2021).

It is certainly a proof that blockchain is going to much more energy-efficient thus naturally its scalability, regarding its 2nd challenge, keeps enhancing as well. Plus, the transaction processing speed of new blockchain mechanisms have been much faster than before as illustrated at Section 1.4. Nevertheless, since the current scale of using blockchain on emission trading is relatively small, neither energy consumption nor scalability has been a significant bottleneck for achieving trust.

However, the third challenge of blockchain application still being immature was, to a certain extent, affirmed by the professional blockchain expert who raised the “double counting” suspicion of Klima DAO. Once proven true, the ethical trust of investing in Klima DAO for contributing towards carbon abatement can drop to freezing point. The stakeholders of emission trading can also cast doubts on whether there should be trust in the blockchain regulator (structural assurance trust) or technological verification procedures (control-based trust). But except for this case, there has not been other evidence discovered through this qualitative research that advocates or opposes against this challenge. In order to reach a level at blockchain application having enough trustworthy track-records specially towards emission trading, considerable amount of efforts from blockchain developers and other stakeholders still need to be made.

In terms of the last challenge: blockchain itself not being able to guarantee quality of the data input to the chain. The empirical examples displayed at Section 1.4 including the use case of Khaqqi et al. (2018), Richardson and Xu (2020) and World Bank (2020), have all proposed combined applications between IoT and blockchain that had guaranteed that real-time data quality. Besides them, the NRGCoin experiment case included at Phase One of this qualitative research can again prove the feasibility of this solution (Mihaylov et al., 2018). Additionally, as one of the inventors of NRGCoin, the academic blockchain expert interviewed also affirmed this combined solution could factually guarantee the authenticity of energy consumption data. Hence this 4th challenge should not be classified as an inhibitor for blockchain application in the setting of emission trading.

5.3 CONSOLIDATED TRUST MODEL

All five proposed trust determinants from reviewing literature, along with one newly proposed trust factor from an expert, have been thoroughly analysed and discussed at the Results Chapter. However, the connections between the suggested Pyramid and Sequential models have not been visualised. Also, these two models only depicted certain probable relationships between the trust factors, but they did not reflect the relationships between trust factors and the dependent variable, which in this qualitative research is: trust in blockchain application at the setting of emission trading. Therefore, based on the key findings: structural assurance trust, knowledge-based familiarity trust and control-based trust being key determinants; peer-based trust, situational normality trust and ethical trust being potentially influential; in addition to the two proposed trust models, a consolidated trust model for this research is demonstrated as below as Figure 6.

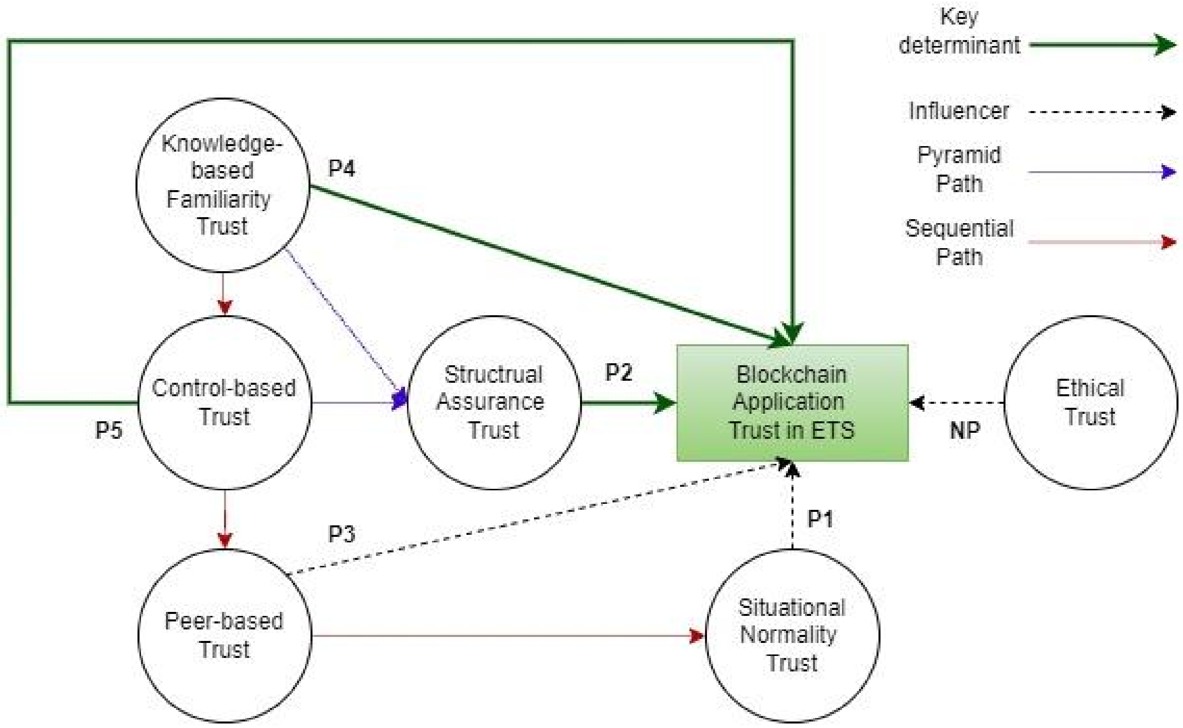


FIGURE 6 CONSOLIDATED TRUST MODEL

Nevertheless, this research is exploratory, this model is formulated according to the analysis outcome of qualitative data but there has conducted any quantitative analysis to verify strength of each correlation. Therefore, within the scope of this research, the author cannot refer this consolidated trust model as conclusive. It is the most sensible model for this exploration.

CONCLUSION

6.1 HIGH GENERALISABILITY

ICAP and World Bank (2021) emphasised in the emission trading handbook that the political landscapes can vary significantly between countries. A carbon pricing approach suitable for one country may not fit for another. Hence, when composing climate jurisdiction system and choosing policy instrument, each government should make the most suitable strategy considering their local context. However, in the case of Finland, to a large extent, it is not necessary to customise, since the country should suffice to achieve their carbon-zero goal, via following the EU ETS.

For instance, the experts of Finnish Energy Authority referred the calculation of allocated allowances is conducted only at EU level, "We don't as a government give out the free allowances, the EU Commission goes through every calculation. So, no country has the power to decide how much they want to give out to their own installations"; then they continued, "Each calculation goes through the EU Commission. And the rules are same for all countries. And nothing can be handed out in the Registry before the Commission has gone through the calculations". Same applies to delineation of caps for the emitters in Finland, "In the EU ETS cap and trade system, the cap is EU wide. So, we don't have a national cap". Also at the national level, the Authority can only verify if the entities are factually "Who you say you are", but "Verification of the installation and verification of the emission amount was correct" are handled by the ETS "Bank". Therefore, within EU ETS, there is currently not too much room to be tailor-made at least on a Finnish national level.

On the other hand, although Ministry of Economic Affairs and Employment of Finland (2022a) stated that Germany and Poland opted out from the designated EU general carbon auction market (see also Section 2.2), the ETS experts have actually told the opposite, "Under EU ETS, some countries have decided to have their own auctions, but it's the same allowances and you can still trade them across the countries", "that is a Finnish company can make some sort of trading with the Germany standard German company".

Therefore, the emission trading system of Finland can be a representative of most countries under EU ETS. Even though this research has only focused on Finland and conducted interviews only with Finnish ETS experts, the trust factors in using blockchain for emission trading generated and analysed through this qualitative research, should be highly generalisable among European Union countries. However as described in Conceptual Background Chapter that the largest CO_2 emitting countries like China, Korea and Mexico have adopted rather different emission trading strategies even starting from trial approaches. The generalisability of the trust factors verified by this research can be lower towards countries outside of European Union. Moreover, the academic blockchain expert also confirmed that it has been remarkably hard to promulgate blockchain knowledge further or more general blockchain adoption. Nevertheless, this restriction of generalisability has been largely mitigated because numerous use cases from the selected empirical reports were in non-EU countries. Particularly, the introduction and analysis of ethical trust in blockchain application were predominately concerning less developed countries (see also Section 4.6).

All in all, the results of this qualitative research should be considered highly generalisable thus with high external validity.

6.2 LIMITATIONS

In spite of the fact that there exists limited amount of empirical research papers focusing on how trusts can be achieved whilst applying blockchain, let alone specifically to emission trading. The author has attempted to secure the reliability of this research via a two-phase research design. Also, within each phase, qualitative data from two different aspects has been collected. At Phase One there has been 5 empirical reports plus 3 academic papers, while at Phase Two there has been an interview with two emission trading experts plus two interviews with two blockchain experts. However, doubt of reliability can still be casted onto the research. For instance, most use cases from the 8 empirical papers are not related to applying blockchain to emission trading but applying blockchain to other sustainability fields. Should those trust elements be reliably grounded to justify the proposed trust determinants remains a subject of discussion. However, the expert interview should to a large extent fill in this void of lacking concentration on emission trading. Because the interview with the ETS experts was solely about emission trading and the professional blockchain expert has been working directly on projects which applies blockchain to emission trading over the world.

Nevertheless, the reliability of this research could have been increased if more expert interviews could be conducted, especially when the interviewed experts would have profound experiences in blockchain application to emission trading. Under the time restriction of this master thesis research, this was unfortunately not feasible.

Finally, the internal validity has been ensured via the structural research processes: 1) proposing five trust determinants based on highly credible academic literature, 2) justifying these determinants by conducting grounded theory on eight empirical papers, 3) verifying the proposed determinants once more by interviewing four experts, 4) proposing a new trust determinant as well as correlation models of the trust factors by analysing interpretations of the two blockchain experts. These procedures were constructed to form full coverage of the three components of research topic: blockchain application, emission trading, and relevant trust elements. Particularly, the double verification of step 2) and step 3) has heightened the internal validity of the qualitative results obtained. Nevertheless, both components of blockchain application and emission trading are novel fields, plus a combination of these three components is nearly unprecedented. Therefore, the internal validity is destined to be limited.

Similar to the judgement on reliability, limitation of internal validity of this exploratory research could have been lifted if profound amount of extra empirical materials could be grounded and more strongly relevant expert interviews conducted. However, within the time restraint of this master research period, that would not be feasible.

6.3 FURTHER RESEARCH

The trust models proposed by this research including Sequential Model, Pyramid Model and Consolidated Model can all be considered utilised for scrutinising future blockchain applications to emission trading or to other emission abatement projects. Future research should be conducted to investigate the validity, completeness especially generalisability of these proposed models.

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