Forundersøgelse om anvendelsen af Blockchain-Teknologi på markedet for CO2-kompensation

Feasibility Study on the application of Blockchain Technology in the Carbon Offset Credits Market

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1 Introduction

The human environmental impact has been discussed a lot during the past years and not taking any action can result in catastrophic consequences. This research main goal is not to raise awareness towards global warming and the future of our species, but it is necessary to briefly contextualise in order to understand the value of the proposed research.

It is now more than ever clear, how human activities are impacting the environment and causing some anomalous changes (changes that would not occur naturally). These changes are also due to the extreme CO_2 emissions together with some other greenhouse gases and they can cause various unbalances in the natural world, such as the extinction of some animal and/or plant species (Hughes, 2000). As a plausible response, multiple government decided to sign and adhere to the Paris agreement, signed by 196 Parties on the 12th of December 2015 and entered into force on the 4th of November 2016. The Paris agreement is a legally binding international treaty which aims to limit the warming of the globe to below 2 degrees Celsius, preferably 1.5 degrees Celsius (compared to pre-industrial levels). When signing, each of the participating Parties made the statement that they will put effort into reducing their national emissions, this oath is materialized through the country's plan for climate action also knows as nationally determined contributions (NDCs). Each Party should have submitted their plan by 2020 (United Nations Framework Convention on Climate Change 2022). However, the Paris agreement provides a framework but does not provide any particular policy or strategy on how the goal should be met. The signing Party is responsible for finding and implementing a feasible solution (or multiple solutions), in order to achieve their NDC, as well as significantly contribute to the global fight to the fast climate change. Unluckily, regardless of the commitment of the signing countries, the green transition comes with its complications and socioeconomical challenges, which are making it hard for countries to quickly move to relying on renewable solutions only (Hafner & Raimondi, 2021).

One of the current solutions to cope with the high emissions, is to exploit carbon offset credits. Fundamentally, a carbon offset credit is a certificate that represents the compensation of 1 (one) tonne of CO_2 gas. The compensation is done through various technologies and projects. These project vary in nature and they go from reforestation, to manure biogas control or gas collection and destruction at landfills (Kollmuss et al., 2010). At the current state, there are two main offsetting markets: the compliance market and the voluntary market. The compliance projects focus more on technicalities and calculations, to guarantee a "high quality" credit. The voluntary market is less regulated and pushes on the narrative rather than the absolute perfection of the calculations, in this case the buyer feels more involved, so to speak, and can handpick specific projects that they want to indirectly finance through the purchase of the credit (H. Lovell & Liverman, 2010).

The buyers of carbon offset credits are both individuals (e.g. when paying a premium for a plane ticket in order to compensate for the flight) and corporations. When talking about individuals, the main reason for offsetting emission is good faith as it is a voluntary contribution. For corporations, the situation is different and there are multiple cases to be considered. First of all, businesses have a maximum threshold of allowed emissions (depending on the country in which the business is conducted the threshold might vary or be completely inexistent) on top of the environmental taxes. All the emissions exceeding the threshold are fined if not compensated for (European Commission, 2010)(European Union, 2003). Secondly, a business might decide to aim at a zero emissions goal, therefore compensating for all his emissions (even though not strictly necessary by law). When a business decides that it needs or wants to compensate for emissions, the easiest choice is to buy carbon offset credits and keep the business running as it is.

It is ultimately the business's owner (or owners) responsibility to decide whether they want to achieve net-zero emissions through the compliance or the voluntary market (or if they do not feel the necessity to become net-zero at all). As it turns out, the preferred option varies quite a lot depending on some specifics such as the for-profit versus non-profit nature of the business and the business size (Poudyal et al., 2012), it is then hard to point at a specific target for either markets. This directly means that both methods (compliance and voluntary market) have their share and are fundamental in the carbon offsetting market.

Given the ever-growing thrive for net-zero emissions (FCLTGlobal, 2022), the demand for offset credits keeps increasing and is expected to grow more and more in the upcoming years (Trove Research, 2021).

However, the voluntary carbon market (VCM) has some major flaws. Since it is not as regulated as the compliance market, there often is a significant level of uncertainties regarding the quality of the credit and on the credit's origin. Some credits are in fact not standing up to their claims, and the only way to find out whether a voluntary carbon credit is legitimate is to visit the site of the project or to talk with an expert that has knowledge about the project. This issue is partially solved through so called standards. Both compliance market and voluntary market have their own standards. A "standard" is basically a certification, performed by a third party, that confirms the legitimacy of the offset project. Auditing a voluntary carbon offsetting project gives some security on its legitimacy but the lack of regulations makes it hard to judge whether the project is complying with its claims and whether the audit actually ensures the quality of the produced credits.

On top of that, there often are some double-counting of credits issues. Let's make an example to explain this phenomenon: Let's assume that an airline A, located in Denmark, offers to individuals the possibility to offset their flight through a premium when purchasing a plane ticket. Their offered carbon offset program consists in planting trees in Nicaragua. Now the problem arises, should Denmark count the offsets generated by this project as the home country of the company, or should Nicaragua count them as hosting country? Once again, this case is regulated in the compliance market, while the compliance market lacks relevant law. This regulative hole can then cause such problems and conflict of interest. Nicaragua, as host country, should allow Denmark to count the credits as their own, and Denmark of course wants to do so in order for the project to contribute to their NDC, but so does Nicaragua. This discrepancy often results in both countries counting the credit, effectively meaning that some emissions reductions are counted but not actually compensated for.

It seems that the compliance market would then be the obvious choice when it comes to compensating for emissions, but there are advantages in the voluntary market as well. First of all, given the unregulated nature of some projects it can often offer very competitive prices. The regulations-heavy counterpart (the compliance market) cannot be competitive in that sense, as all the needs for certifications, specific machinery, time requirements and so on, tend to drive the price of the product upward. A lot of corporations are then willing to finance the voluntary market, simply due to a financial advantage.

It is important to note that not all projects in the voluntary carbon market are fraudulent, there are indeed projects that are effectively reducing emissions and are properly counting their credits, but the problem lies in identifying these projects and separating them from the fraudulent ones, as well as in regulating the market and setting some ground rules to avoid accounting problems.

The major flaws in the markets are then: The excessive and compulsive precision of calculations that takes away the importance of the underlying project and drives the price of the credits up for the compliance market, and the double counting together with the unreliability of the credits for the voluntary market (H. C. Lovell, 2010).

This is the first confirmed premise: the carbon offset credits market is necessary (both compliance and voluntary markets), but suffers from some major systematic issues.

Let's now introduce the concept of blockchain technology, and see where the value proposition lies when applied to this space. The blockchain is, in very simple words, a shared, decentralized database. It relies on mathematic encryption principles, such as the hashing function, in order to offer a secure and reliable database (Zheng et al., 2017). Usually these database are used in order to store transactions, similarly to a centralized bank database. The key difference is the decentralization of blockchain, compared to the classic centralization of institutions. To make an intuitive example, if by any chance your bank should be hacked or by mistake delete all their database, there would be no way of getting the data back and restore a precedent functional state. This is because all the information is centralized, there is no physical copy of every transaction anymore, everything is digital. Even though there are safety measures, it is possible that such an event could occur and basically drain every client's account (or debts for what it's worth). Now, this is a very unlikely scenario, but it's presented in order to make a point. On the decentralized blockchain, you have the freedom to "download a node", meaning creating a copy of all transactions that ever happened on the blockchain and contribute to the ecosystem. Everyone is free to do so and no one owns "the original", because every ledger (copy of all transactions ever performed on the blockchain) is updated simultaneously and data is not streamed in a pyramid-like structure, but directly to all the other peers of the network (Drescher, 2017). This means that if any user was to lose his laptop containing all the transactions ever performed on the blockchain, he could just buy a new device and download another node, and all the information would be exactly the same as before (plus of course, the updated information of all the performed actions that happened in the period that the device was lost).

Furthermore, blockchain offers security about the legitimacy of transactions as well. Through what is called a "consensus protocol", the blockchain only allows transactions that are actually valid. For example, if a user tries to send 1 bitcoin to a friend and his balance is 5 bitcoins, he will be allowed to do perform the transaction, but if he tries to hack the system and spend 1 bitcoin while his balance is only equal to 0.5 bitcoins, the consensus protocol will spot the misbehaviour and block the transaction. There are multiple consensus protocols and the most famous ones are Proof of Work (PoW) and Proof of Stake (PoS). However, new consensus protocols and new blockchains that rely on them are emerging at a rather fast pace. Each consensus protocol has their benefits and limitations and it is not intent of this paper to deeply investigate each one of them. The key point is that these protocols make transactions as secure as virtually possible (there is virtually no way to hack the protocols).

Another fundamental aspect of the blockchain is that it's public. The record of all transactions ever performed on the blockchain is available to the public and anyone can verify whether a transaction happened or not. This might look like a downside regarding the users privacy, but it really is only in certain situations. The blockchain is so called semi-anonymous, or pseudonymous, this means that every user is not represented by their name, but by a pseudonym. This fictitious identity is usually what we will be referring to as "public address", it is a long string of characters and/or numbers that represents a specific account (or "wallet", to introduce the proper lingo and terminology). Only the account's owner is able to perform transactions from said account, but everyone can see the transaction. So when a user sends 1 BTC to someone else, everyone will be able to see the public address linked with the user's account (which as we discussed, is his pseudonym), the receiver's public address and the transaction amount, but no one will have knowledge about the user's identity. The user is then kept anonymous. Of course, if the user gives some kind of proof that he is the owner of that specific public address, or if someone discovers that a certain address is linked to the user's persona, then anonymity is lost. Anonymity is not fundamental to all users, but it is often a requirement in order to justify the public nature of the blockchain.

Nordic Waves Group (from now on referred to as "NWG") is a start-up with specialization on circular economy and the carbon offset credits market. To briefly cite two of the main services offered by NGW: they play the role of connecting reliable carbon offsetting projects and carbon offset credits buyers, and they will soon start offering private counselling to clients who are seeking guidance towards circular economy or net-zero emissions.

Something to be noted, is that this research is conducted as a mandatory Bachelor Project which lasts 6 months. However, the project itself does not have a 6 months deadline but will potentially take longer to be implemented (if the result is positive), it will hence not be finished and implemented by the time that this document is submitted. The purpose of this document is to discuss and go over possible applications and advantages of the blockchain in this specific use case.

After finishing this document, the reader should have a clear idea on the advantages or disadvantages of applying a specific technology relying on the blockchain to the voluntary carbon offset credits market, as well as have an idea of what such a product could look like. This document aims at being a framework or a starting point for the creation of a blockchain solution to the VCM.

Due to the joint nature of this research (between the author and NWG), the research will be executed in close contact with Nicolai Alexandrowski (CEO) and Michael O'Toole (colleague). This research can be read in general terms, but some particular notes regarding NWG will be made.

2 Methods and Materials

The fundamental question that needs to be answered before starting the development, regards the advantages and/or disadvantages of using blockchain technology, the feasibility (technical and from a business perspective) and the time requirements. Once these considerations are made, the project will be decided to be either a GO or a NOGO project for act4 (act4 is the NWG branch responsible for the VCM-linked actions). The assumption is that blockchain technology can be usefully applied to the Voluntary Carbon Market, but sound data and studies are needed to back this claim.

This research aims to answer these questions and set a sort of framework, that might in future be applied to the development of a Proof of Concept and a complete product later on in the act4 environment, while also being valuable for other organizations that wish to create a similar solution.

This analysis has multiple steps to it, some of which will be investigated in a qualitative way, and some that will be investigated in a quantitative way. The areas of interest are: finding the pain-points in the Carbon Offset Credits voluntary market, showing how the blockchain technology can solve some or all of the issues in the voluntary carbon market (VCM), investigate existent use-cases in this scope, investigating different blockchain technologies (fungible tokens and NFTs) and their applicability to this scope, and finally investigate the best blockchain that can be used to implement this application.

It is to be noted that the carbon credits offset market includes more areas than merely the VCM (as explained in the introduction), however, in order to have a discussion that is not dispersive, only the VCM is investigated. The VCM is chosen particularly because it falls within NWG acting scope and because it suffers from some systematic flaws. The VCM pain-points will be found and discussed in a qualitative way, through the gathering and review of relevant journals and through resources already gathered by NWG.

The problems linked with the VCM and the understanding of the blockchain will be addressed through literature review (articles and journals) as well as other information media (such as video-articles, web-articles and similar). The data will be selected trying to keep an unbiased view, and extrapolating quantitative data wherever possible in order to better materialize the matter. The objective is to have an unbiased result; hence, information that would compromise the project will be taken into account as well.

The investigation of similar products will be conducted by navigating the internet and looking for what could be defined as "competitors". Particularly, other solutions to the addressed problems will be taken into consideration and their problems or qualities will be highlighted. The purpose of this research is to determine whether act4 can have a competitive edge in the market or not, as well as trying to have a clear overview on the ecosystem in order to look for flaws and possible improvements that will be addressed when theorizing a solution.

Once a general overview of all the aforementioned topics is clear, a solution should be theorized in all its details. The possibility of implementing Non-Fungible Tokens (NFTs) will be considered and discussed. Through a comparison of strength and weaknesses of simple fungible tokens versus NFTs, it will be decided whether one or the other (or a mixture of both) should be used as representation of a Carbon Credit. Since a customer survey has not been conducted, but ultimately what matters is their wills and desires, the strength and weaknesses to be taken into consideration will depend on the VCM demands and not on my subjective view. To make a comprehensive example: I might find that the unicity of NFTs is a big point in their favour, tilting the scale towards them, but a customer might not find this characteristic as interesting or as valuable. In this case, my parameter's weight choice would over-influence the comparison, possibly indicating the wrong result for the client. The real interests of clients will be assessed through paper reviews and NWG resources mainly, but a partial answer should already have been given when discussing the first point of the research (pain-points of the VCM).

Once the underlying technology is chosen, the last choice to be made regards the actual blockchain that will be used to implement the solution. This seemingly easy part actually represents one of the biggest challenges, as there are new blockchains being developed at a constant rate, some for very specific use cases and others for very broad applications. In order to make the selection, some parameters have been selected based on NWG ideals, act4 team's experience and knowledge, and other fundamental requirements. A general case that can be valuable to any other reader will be presented as well. The selection will be done through a funnel-like structure, where only the blockchains that satisfy certain requirements are pushed on to the next level, and then the process is repeated. The selection process is as follows:

There are four larger types of blockchains: public blockchains, private blockchains, consortium blockchains and hybrid blockchains. As this research is not an in-depth review of the differences, they won't be discussed in detail. The important bit is that only public blockchains are fully decentralized, while all the other types have some level of centralization. For this use case, it is a fundamental requirement for the blockchain to be fully decentralized, since that is the characteristic that got act4 interested in the technology in the first place. The full decentralization removes the need for trust in third parties, both from act4 to the blockchain centralized party, and from the customers to act4 (this would only matter in the case that act4 developed a proprietary blockchain, which is not planned for, but it is an important point to be made).

Since the blockchain protocol also needs to be reliable and ultimately widely used, and since there is not such a thing as a "public blockchain list", a top 20 of the most widely used and/or promising public blockchains is taken into consideration. This initial choice guarantees a level of reliability (since the network is constantly active with big volumes and hence continually empirically tested) while also guaranteeing that there are multiple ways of interacting with the blockchain itself (things such as software or hardware wallets, documentation, audits, and so on). A list of the selected blockchains is visible in the results and findings section. Also note that there currently are various so called "Layer two" solutions, but they will not be considered in this research. Layer two solutions rely on an existing blockchain and somehow improve the performance of the Layer 1 (original) technology, however they are particularly hard to understand and interact with and are hence unappealing to new customers and/or unexperienced users of the blockchain space.

Once our initial sample is selected, there are other fundamental requirements that need to be taken into account. At this stage, the act4's Blockchain R&D team is composed by two persons, both working as part-time volunteers, while other software developers involved with NWG are currently working on different projects. This small team is by no means expert enough to take on a particularly difficult project, and this results in the goal being the assessment of the feasibility for this small team to develop a prototype. However, there are other aspects that given enough funding and expertise (meaning having a team of skilled software developers working on the project), might take the priority. The filtering process will hence be made twice, once keeping in mind the limitations of act4 and the team, and the second time taking an ideal case into consideration. The first result (feasible case) will then indicate a blockchain protocol that easily allows for an implementation in the VCM scope, both for act4 and more generally for any small to medium business that wishes to develop a solution for the VCM. The second result (ideal case) will yield a result that shows the most optimal protocol to be used, protocol that should be chosen by a bigger organization that wishes to develop a solution in the space and has more means (such as a team of experienced developers). Having both the ideal scenario and the feasible scenario will also show the differences in the two, giving an overview on whether a competitive edge can be kept even in non-ideal conditions. The order and relevance of the filters will hence be altered in the ideal scenario. Note that the two results might coincide.

The very first level (the decentralization) is not affected by this situation, as it remains the very first fundamental requirement in both scenarios. To clarify the indexing: this also means that whenever a filter is referred to as "first filter", "second filter", "third filter" and so on, it is actually applied after the initial decentralization filter. For example: the first filter being X, means that X will be applied to the already chosen database of 20 public decentralized blockchains.

The first filter for the so called feasible case, is the possibility to implement smart contracts. A smart contract is fundamentally a deterministic software that only performs certain actions when previously set conditions are met and that interacts with the blockchain (Ene, 2020). If a blockchain supports smart contracts, it means that anyone with some coding skills can develop and deploy their own application to the blockchain, making the application immutable and available to everyone. The interesting bit about smart contracts is that they exploit the blockchain's nature to allow for transactions that usually need a middle-man to be performed by immutable software instead. Escrow is the most straight-forward example: Instead of having a third party temporarily holding onto the funds, a piece of software can lock the required amount of funds and only complete the transfer once the bought asset is handed over to the buyer (note that the asset must obviously have some kind of blockchain representation as well to make this possible). The seller only needs to verify that the software is holding the funds to be sure that he will receive the decided amount. If any party tries to commit fraud (by handing over the wrong item or by not locking enough liquidity), the transaction is considerate as illegitimate and the software will take care of refunding both parties. Blockchains that do not support smart contracts are very hard to interact with and usually only allow for a decentralized payment network. Act4 doesn't aim at implementing a blockchain solution for payment of credits, but rather at representing said credits as assets on the blockchain. Smart contracts are hence the first necessity for act4's blockchain project. Only blockchains that can implement some form of smart contracts will be considered in the next step.

The second filter for the feasible case, is the support of solidity or another mainstream coding language (such as Python, C++, JavaScript, and so on). As previously mentioned, the team is currently very limited both in expertise and number. This means that in order for the project to be technically feasible, it should not be an extreme challenge given the current knowledge of the team's members. Solidity is natively Ethereum's blockchain coding language and due to Ethereum's fast growth, it quickly became the reference language when dealing with blockchains and smart contracts. Solidity is the most widely used blockchain coding language and is fairly simple (it is a hard task to numerically determine the difficulty of a language, but for reference it has some similarities with JavaScript and Python), has the biggest community, has the most information, has the most projects and is currently supported on a lot of different blockchains. This fundamentally means that it currently is the easiest possible way to interact with a blockchain. The biggest point is the availability of a big community that throughout the years got familiar with solidity. This also includes the fact that most of the questions or issues that the team might run into, will already have an answer somewhere on the internet. As one can imagine, the situation is fundamentally different in the case that the considered blockchain is not as popular and uses a different language. To avoid spending unreasonable amounts of time trying to solve an issue on a language that is not well documented, the native support of solidity or other mainstream coding languages is absolutely necessary for the project to be feasible. Only blockchains that are solidity (or other mainstream coding languages) compatible will be considered in the next step.

The third filter for the feasible case is the possibility of creating on-chain Non-Fungible Tokens (NFTs). This will deeply depend on whether NFTs will be determined to be a useful technology or not in this case. It follows that if NFTs are decided to be a valuable technology in this use case, the underlying blockchain needs to support NFTs. However, in the case that NFTs result to be fundamentally irrelevant for this application, this filter will not be considered. If relevant, only blockchains that support NFTs will be considered in the next step.

The fourth filter for the feasible case is the blockchain's sustainability. Since act4 is in the sustainability and circular economy fields, it is important that each project has some special regards for these topics. The blockchain obviously requires energy to function. Since it is a decentralized network it is hard to ensure that only green energy is used by the blockchain, but it is still important to have an eye on consumption and consequently possible pollution generated just by interacting with the network. This means that it is important to pick a technology that pollutes as little as possible. A blockchain consumes energy mainly depending on its so called “consensus protocol”, which is what is responsible for validating transactions. A technical discussion about consensus protocols is not particularly relevant for act4, but the mechanism will be considered since data about the actual consumptions of specific blockchains is sometimes non-existing or unreliable. This represents a problem since it makes it impossible to give numerical values to some consumptions. However, two documents giving an overview on the average consumptions linked with specific consensus mechanisms will be consulted since they give a clear enough overview and will help in making a choice. Such documents are: “A Review of Consensus Mechanisms and their Energy Consumption” (Bada et al., 2021) and “Research on Progress of Blockchain Consensus Algorithm: A Review on Recent Progress of Blockchain Consensus Algorithms” (Xiong et al., 2022). This filter is the first filter that does not have a clear cut anymore, if on previous levels a blockchain simply either satisfied the requirements or not, in this case it is different. Since there is another filter to be applied after this, the top 5 performing blockchains (meaning the 5 blockchains that are found to consume the least energy) will be brought to the next and final step. The choice of the number (five) is arbitrary, assuming that this amount will give enough possibility for the final selection while also removing the most polluting solutions.

The fifth and last filter for the feasible case is the cost associated with each transaction or interaction with the blockchain. Each blockchain protocol has costs associated with a transaction, meaning that for example if a user wants to transfer 1 ETH from his account to someone else, he will actually spend 1.001 ETH (note that the estimation is not accurate but is solely used for explaining purpose). The transaction costs vary from protocol to protocol and it is in act4’s best interest to have the lowest transaction cost possible, as a high tx (short for “transaction”, often used in the blockchain space) cost would be a major deterrent for adoption. As previously stated, by this time we should have a maximum of 5 protocols to make the final choice. The one blockchain that offers the cheapest transaction costs will be the one selected for the project prototype/proof-of-concept development. It is important to note that transaction costs also vary depending on the network activity. Typically the more transactions are happening simultaneously, the higher the transaction cost will be. This makes it hard to clearly state a specific transaction cost for transactions as they might vary over time. On top of that, transaction costs vary depending on the taken action, meaning that interactions with smart contracts have different costs than transactions. Furthermore, smart contract can be “gas-optimized” meaning that the interaction costs will be contained due to the way the contract is written. The cost will then be determined through an average of the last 20 transactions that happened on the blockchain. The data will be gathered in a small period of time assuming that network activities will vary similarly throughout different networks. Particularly, the process of determining average transaction costs will be limited to two days and the data will remain unchanged after the investigation is completed. This is done since it is unavoidable for prices to not constantly change, given the very volatile nature of cryptocurrencies. The data will be taken directly from the so-called “block-explorers” of the specific blockchain under review. A Block-explorer is a website that gathers data from the blockchain and gives all kind of information regarding transactions, including the transaction costs. The costs will be expressed in US dollars to have a normalized meter. Note that even though the smallest portion of an American Dollar would be 1 penny, or 0.01 dollars, smaller values will be not rounded up as cryptocurrencies often allow for smaller fractions of a unit. In poor words, this means that in principle it is usually possible to transact cryptocurrencies in a quantity that is worth less than a penny.

A list of all the considered transactions will be available in the appendix and given the nature of the blockchain technology, the results will be reproducible at any time in the future by anyone. To replicate the results, it is enough to visit the block explorer, look for the stated transactions and repeat the process.

The used block explorers will be linked in the relevant results and findings section.

The only exception will be a particular blockchain, called the NEO blockchain. The NEO protocol has a peculiar way of charging transaction costs, particularly the cost depends on the transactions data and on the interaction that the user wishes to have with the blockchain. Transactions up to 1024 bytes of data are free, while transactions over 1024 bytes of data have a cost of 0.001 GAS (NEO protocol transaction fees token is called GAS) and a surplus of 0.00001 GAS per-extra-byte is added (NeoDocsBuilder, 2021). Furthermore, when interacting with smart contract any transaction that would cost less than 10 GAS is free, while if a transaction is particularly heavy and would exceed the 10 GAS limit, it needs to be paid for. How much specific interactions cost depends on the used method (NeoDocsBuilder, 2021) and it would be close to impossible for someone without a very consolidated technical knowledge to come up with an estimate. Given this situation, a transaction's average cost will be determined to cost 0.001 GAS, as it is unknown whether the threshold would be surpassed often or not.

A schematic of the filtering and selection process for the feasible case is shown in figure 1.

The process will be repeated for the ideal case. This process should output the best blockchain protocol to be used for a VCM application, regardless of the limitations. In this case the filters will have the same premises and meaning as for the feasible case, but will be applied in the following order instead:

The first filter for the ideal case is the possibility to implement smart contracts, which regardless of the resources is strictly necessary to develop a blockchain application.

The second filter for the ideal case is the transactions sustainability, the filter is applied in the same way as it is in the feasible case (top 5 technology will make it through). This filter is not strictly necessary per-se, as a business might as well not care about being green and still operate in the VCM, however, due to the ideals brought on in this research (and assuming that a business operating in the VCM has in fact interest in keeping low consumptions), the sustainability of the underlying technology is considered to be necessary to be addressed in the ideal case as well.

The third and last filter for the ideal case is the transaction cost, which would still represent a deterrent if too high. The technology that performs best in this category will be the final result for the ideal case.

As you might notice, the support of solidity is not an important factor in the ideal case. This is because, as discussed, the assumption is that a team of talented software developers would be available. The same goes for the support of NFTs, since they are at the core just an application of the blockchain, they can be in principle created on any blockchain that allows for the deployment of smart contract (which is taken into consideration). The key difference is that some blockchains have so called "standards" that allow for a very easy and straight forward process of creating NFTs. Without these standards, the whole process becomes more tedious and complex. In the ideal case, this would however not represent an issue.

A schematic of the filtering process for the ideal case is shown in figure 2.

Once all the steps discussed from the beginning of the section until now are completed, we should be left with a clear overview of a possible application of the technology that solves some pain-points as well as have an educated choice for the underlying technology, based on the discussed parameters.

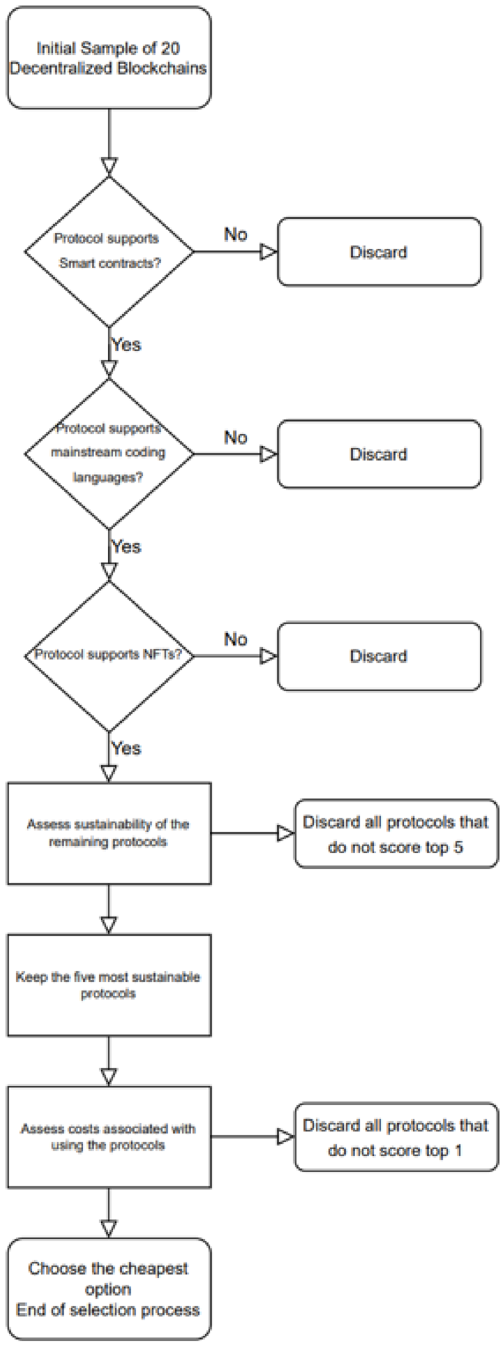

Figure 1: *Selection process for the feasible case*

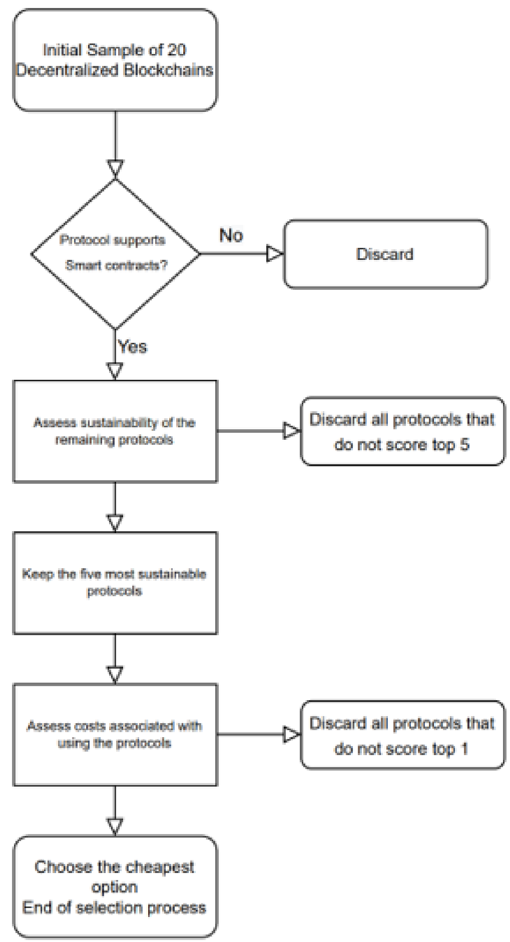

Figure 2: *Selection process for the ideal case*

3 Results and Findings

This section will present the results of the conducted research. Note that each chapter is independently sufficient to gain information and understand the relevant findings. Also note that chapter 3. "Theorizing a Blockchain Solution and Discussing Blockchain Technologies", while still being independently sufficient, also relies on the findings of chapters 1. "Voluntary Carbon Market (VCM) Pain-Points" and chapter 2. "Existing Blockchain Solutions".

3.1 Voluntary Carbon Market (VCM) Pain-Points

As briefly discussed in the introduction, the VCM has some major flaws even though it is a virtually fundamental player in the green transition, at least for the upcoming years. The main problems linked with the VCM regard the almost non-existing regulation and the low availability for organs responsible for ensuring the quality of the credits supplied by a project. This also translates to the existence of issues regarding double accounting of credits. To briefly discuss the double accounting issue: As stated in "Guidelines on Avoiding Double Counting for the Carbon Offsetting and Reduction Scheme for International Aviation" (ClimateWorks Foundation, 2019), there are mainly three types of double accounting: (1) double issuance of emissions units; (2) double use of emissions units; and (3) double claiming of the same emission reductions or removals by both the country in which the emission reductions or removals occur and an aeroplane operator using emission units under CORSIA. Note that these guidelines are specific to aviation, but the issues are present in the whole VCM market, as stated in "Procedures for issuance and withdrawal of Carboncer and double accounting policies" (Cercarbono, 2021). This last document explains particularly well the nature of these accounting issues and makes examples on how they can happen, to very briefly summarize their research: Issue (1), or Double Emission, happens when multiple credits are generated from the same reduction. This can happen for example if two projects are operating in the same area. Issue (2), or Double Use, happens when a credit is used twice. This can happen if a project is simultaneously in multiple registries (the nature and purpose of registries will be explained shortly). Issue (3), or Double Claim, happens when the same credit is accounted for by different entities. This can happen for example if a project is part of a registry, but the host country accounts for the reduction in its national accounting as well. The two main problem areas (lack of jurisdiction and quality control) go hand-in-hand and the result is a relatively complicated system of "registries" and "standards".

Registries are organizations responsible for tracking the offsetting projects and issuing credits. Registries are also responsible for ensuring that a credit is valid and only spent once. Here we can see how if a project is present in multiple registries, it constitutes a problem (see issue (2), or Double Use).

Standards are certifications that ensure that a specific project carbon offsetting actually results in emission reductions. Standards also give general guidelines on how the offsetting should happen (VCMPrimer, 2022). The two documents cited in the previous paragraph, are some guidelines regarding the proper procedures needed in order to try to solve most of the mentioned issued. These guidelines (particularly "Guidelines on Avoiding Double Counting for the Carbon Offsetting and Reduction Scheme for International Aviation") have been discussed and chosen by a group of some of the biggest players in the space (citing from their "about" section: "The Guidelines were developed through a multi-stakeholder consensus decision-making process, by a working group consisting of representatives of the American Carbon Registry, Carbon Market Watch, Climate Action Reserve, Environmental Defense Fund, the Gold Standard Foundation, the International Emissions Trading Association, Verra, and the World Wildlife Fund, with critical input from outside experts."). The guidelines go into great detail about the procedures that a project should comply with, in order to avoid any type of double accounting. A very obvious example is that when a new project is trying to get listed in a registry, it should sign a declaration stating that it is not currently part of any other registry. Note once again how all these organizations and guidelines arose autonomously, without any central authority or government backing them.

When a project wants to start operating in the VCM, they need to be listed in a registry, and possibly earn some certifications (the above mentioned standards). There are however multiple registries and standards, which are appropriate for different projects. For example the gold standard, one of the most widely used, only ensures the quality of project particularly involved with reforestation and afforestation (Gold Standard, 2017). On top of that, any organization that wishes to resell credits also needs to be audited by the registry in which the specific offsetting project is listed. This is currently the situation in which act4 is in. What happens is that projects are usually solely responsible for the actual offsetting, while a third-party contacts customers and sells the credits. The registry has to audit both and is responsible for retiring the credits as well, meaning acknowledging that a credit has already been "used". In poor words, it means that a typical sale of a Carbon Offset Credits in the VCM goes as follows: offsetting project A gets audited by registry X, if the result is positive, project A also is ideally issued with the specific standard H (stamp issued by yet another party). Act4 then also gets audited by registry X and assuming that the result is positive, act4 proceeds to find a customer while project A keeps offsetting, tracking the results and issuing the credits to registry X. When act4 finds customer K that wishes to purchase 10 credits, it sells the credits and then goes on to notify registry X. Registry X retires the credits (keeps track of the fact that those credits have been sold) and issued act4 with a specific code that represents the purchase and the amount of credits. Act4 then takes this code and sends it to customer K, as a proof of its purchase.

It is easy to see how this set-up quickly gets confusing, as there are multiple organizations responsible for the regulation and full functioning of the VCM. This is a very frictional environment and the result is that times are very dilated, while the risk of problems and errors arising throughout the whole process also increases.

Another smaller issue is the difficulty of verification of the purchase. The customer does hold the code linked with the transaction, but in order to verify the source and validity of the issued certificate, the code needs to be sent to the registry, which will return some information regarding the legitimacy of that particular transaction. This process is rather straight forward, but it is another additional step to the already very intricate scheme of things.

3.2 Existing Blockchain Solutions

Before theorizing a possible blockchain solution, it is important to determine whether a functional solution already exists or not. The results are overall not positive. Firstly, the number of existing solutions is very limited. The market research was conducted through the length of 3 (three) weeks, on a daily basis, by 2 (two) persons (particularly me and my colleague) and the number of solutions that even just vaguely seemed to fit our expectations and requirements to be considered (and that we could find and investigate within that time period) is 9 (nine).

Since this document is not fully devoted to the market research side of the project, a detailed review of every project is not contemplated nor presented in this particular instance. Perhaps, it is far more interesting to sum up the findings in a shorter and clearer manner.

Among all the found solutions, there was none that fully satisfied us or that seemed to actually be fully functional and used. This is on one hand concerning as it might seem that such a solution simply is not viable, but on the other hand represents a big market opportunity for act4 and NWG, since in this particular scope the competition is currently virtually inexistant.

The encountered problems in the existing solutions are multiple, and the major ones will be briefly explained:

Firstly, the lack of documentation on most of the projects is particularly concerning. Even though there are indeed projects claiming that they tokenized (meaning representing on the blockchain through a token) offset credits, no project that clearly states how they were achieving this, where the credit originated or the quality of the underlying offsetting project was found. Even the most promising applications, such as the EcoRegistry solution, claiming that they use blockchain in a registry environment, barely have any documentation and there is no way of determining whether their solution is fully blockchain backed (EcoRegistry 2019). Note that this only applies to the credits origin and overall transparency, the technical part (or back-end) is sometimes available as it is published on the public blockchain. The technical part is however of little relevance in this particular branch of the research.

Another major problem that emerged as a constant throughout multiple solutions, is the speculation aspect. Particularly, it seems that even this market can be exploited, meaning that introducing a freely tradable asset that represent carbon offsets (a new token) will attract "traders" and the speculation game will start. This ultimately makes the price fluctuate a lot, as the main interest of most traders is to make money, while they care little about the purpose of the token. The main problems with a fluctuating price and the speculation game overall are two: firstly, at any certain time the credit might be valued at a price that is minor to the actual cost. For example, a credit valued and traded at 1 dollar (arbitrary value) might actually have costed 2 dollars (arbitrary value) to produce. If this is the case, it is easy to see how the offsetting project will have short life as it will constantly be in loss. Secondly, the VCM should not be attractive due to its potential of generating revenue, but should rather be a useful tool to use to compensate for emissions. This means that it should be unattractive to traders, since they ultimately do not care about reducing emissions. Having the same token being sold and bought over and over again might be interesting from a "buy-low-sell-high" perspective, but is useless from an offsetting point of view. On top of that, a speculative token, can attract actors that play in bad faith, and look for possible exploitations in the contract (in the code). This is also obviously very bad as if a mistake, bug, or possible exploit is found, the "hacker" can use that to unlawfully obtain tokens and sell them in mass, driving the price down and possibly completely destroying the token economics (called tokenomics in the space, for short). Two example of tokens with a fluctuating price are presented in figure 3 and 4. An example of a project whose price was fluctuating, but was unluckily also attacked and practically destroyed is shown in figure 5. All three tokens and projects shall remain unnamed, as this is not intended as a direct attack to a specific competitor, but rather a study of behaviours that are unwanted and not contemplated in the act4 vision. However, if a reader wishes to study more in depth any of the presented projects, a link to the charts will be present in the "references" section. From there it will be easy to reverse-engineer the source project and conduct a more detailed analysis.

The next problem that occurs, is the lack of information regarding the underlying offsetting project. To explain why this is a problem, let's make a quick example. Let's say that there are 3 (three) offsetting projects, and each one produces 10 (ten) credits, for a total of 30 (thirty). Company A, inventor of a blockchain-based solution, represents these credits as fungible tokens called CarbonOffsetA (COA for short, abbreviating tokens with three or four letters is very common in the blockchain space) and particularly decides to mint ("minting" is the proper word in the blockchain space for "generating" or "creating") COA tokens at a 1/1 ratio with the actual credits. So, company A, mints a total of 30 COA tokens. Now customer X comes into play and wants to offset 5 tons of CO_2 through project 1 and 5 through project 2. Company A can very well issue 10 credits to customer X and assure that each credit represents an actual offset, but the customer is ultimately left with 10 COA tokens and has no overview over what he actually paid for. This might seem like an insignificant problem, as assuming that all three projects are actually properly offsetting, the result does not change, however as briefly discussed in the introduction section, customers are particularly keen on buying credits issued by projects that are in some way aligned with their hopes, desires and ideals. Not having a clear connection between the tokens and the project might result in less volume, as on the surface it looks like it's impossible to actually pick a particular project.

Figure 3: *First example of a token representing Carbon Credits fluctuation in price over time (CoinMarketCap, 2022)*

Figure 4: *Second example of a token representing Carbon Credits fluctuation in price over time (CoinMarketCap, 2022)*

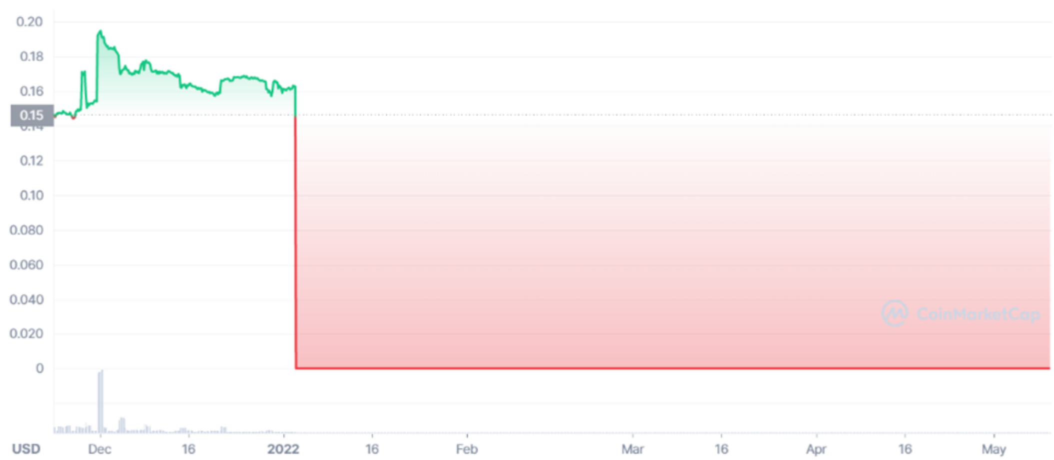

Figure 5: *Example of the price trend of a token that has been attacked (CoinMarketCap, 2022)*

To make a somewhat similar example, it is more likely for people to donate to charity if they can decide where their money is going (through pictures, maps, videos and so on) rather than just paying for "general charity". This is often referred to as the "identifiable victim effect" (Jenni, 1997). It is important to note that this would not result in the complete abandonment of offsetting, but it does put the blockchain solution at a disadvantage. Some customers might think or feel something along the lines of: "Since competitors offer the same service, but they also allow me to hand-pick offsetting projects, why would I go with the more impersonal and generic version of the service?". People love to feel involved, I argue that a fungible token would be a deterrent for a portion of the possible customers.

A fourth issue was found across different solutions. This is somewhat linked to the "lack of documentation" point but it mostly regards technological choices. Particularly, it is sometimes impossible to determine what blockchain protocol is being used (as in the EcoRegistry case, where no information at all is available regarding the specific blockchain solution) and when it is possible, mainly in simple tokenization of credits, the choice almost always falls on the Ethereum blockchain. This is not necessarily a problem as the Ethereum protocol is indeed very useful and resourceful, but what is missing is a motivation for the choice. Picking the Ethereum blockchain is a rather arbitrary choice not backed by any evidence and/or study (or at the very least, this evidence is not available to the public, making it impossible to determine whether the choice was actually arbitrary or not). As previously stated, this might very well actually be the best blockchain protocol to be used, but a deeper investigation is needed in order to determine it.

3.3 Theorizing a Blockchain Solution and Discussing Blockchain Technologies

Before theorizing the solution itself, let's go over the objectives we are trying to achieve, based on the previous sections. This solution aims at solving some VCM pain-points and at minimizing the discussed problems associated with existing solutions. The main pain-points that might be solved through a blockchain solution are:

- The double issuance of emissions units
- The double use of emissions units
- The double claiming of the same emission reductions
- The ease of verification of the source of the offset

Note that the lack of national or international regulations is not taken into account, as it is a problem that is not solvable through the application of a blockchain solution.

The problems linked with existing blockchain applications that we seek to solve are:

- The lack of documentation and overall clarity
- The justification for the use of a particular protocol
- The speculation aspect
- The impossibility of picking a specific offsetting project

Depending on the solution, which can vary from easy and fast to implement to hard and time-consuming, it is possible (on paper) to solve one or all of the VCM pain-points and to solve one or all of the problems associated with existing blockchain solutions. In this instance, given the "feasibility study" nature of the research, the goal is to pick the easiest solution that can solve at least one of the pain-points and possibly solve most of the tokenization-linked problems (as the solution's goal is ultimately to be used). However, a brief discussion regarding other solutions that would potentially solve more pain-points will be made in the Conclusions section.

Now that the objectives are set, we can start theorizing a blockchain solution. First of all, it is fundamental to theorize a solution that would not suffer from any of the problems that afflict existing solutions, as it is important to have a competitive edge as well as having an actually functional solution.

Following the previously presented list, we should start with a solution that does not lack documentation, transparency and clarity. This is easily done by carefully documenting the process and disclosing as much as possible, and this very document is the first step of that process.

Regarding the lack of justification for the use of a particular protocol, this directly translates in act4 wanting to make a wise and weighted choice. The detailed modus operandi to make this choice has been presented in the "Methods and Materials" section and the results of the investigation will be presented further in the document, in the Results and Findings section point 3.4 "Picking the proper blockchain protocol".

The speculation aspect is harder to manage, as the existence of a secondary market on the supplied product does not depend on act4 practices (or any other actor). However, it is possible to exploit the methods of the blockchain to make it very hard for a secondary market to form and to make it disincentivising for traders to join the market in the first place. Such solution simply consists in applying a "non-transferable" boolean flag to the tokens smart contract function responsible for handling transfers (Crypto Market Pool 2022). Any time that a user tries to sell or swap their NWG tokens the transaction is stopped and reverted (not allowed for). On top of that, it would be possible for NWG to set a fixed price on their tokens, by only making it possible to buy them with stable-coins (a "stable-coin", is a cryptocurrency/token that is by code pegged to a recognized currency, typically United States Dollar). There is a small note to be made here: NWG is also working on a virtual reality space, and it was thought of the possibility of connecting said world to the blockchain and the NWG token that could then be used for all sorts of things (e.g. attending virtual events, buying virtual NWG goods, playing virtual NWG games and so on). If the token is non-transferable, this would of course be impossible. There are however many possible work-around this potential problem, for example it would be possible to airdrop ("airdrop" is a term used in the space that means "give for free") a second coin (transferable and usable in the virtual world) to whoever buys the offsetting tokens. Doing so would allow for the credits to be stored and non-transferable, while also allowing for a secondary market to generate around the secondary token.

The problem regarding the impossibility of picking specific projects, can be solved by implementing NFTs (short for non-fungible-tokens). This type of token, compared to the fungible counterpart, is unique and irreplaceable. This particularity makes every NFT distinguishable from similar tokens, even if their source is the same. NFTs have the peculiarity of being tokens that can store some kind of extra data, specifically called metadata (Guadamuz, 2021). This feature gives creators the ability to generate NFTs collections formed by multiple tokens that are all belonging to the same project but that are also fundamentally different from each other. This technology can be used in the VCM scope as well. Particularly, this technology potentially allows for the creation of tokens that have information about the underlying offsetting project. By utilizing an NFT instead of a fungible token, it would be possible to specify certain traits that belong to that specific token, such as the token source project, a timestamp with the date of generation of the credit, and so on. To make an example, instead of purchasing a generic COA token (the one mentioned in the example in the "Existing Blockchain Solutions" section), a customer could buy a

NWG NFT that holds data regarding the offsetting project. The result would be the same (as both are a digital representation of an offsetting certificate), but the customer could have direct and specific information about the project he is indirectly sponsoring, perk which would not be possible to obtain with a fungible token.

Since we established that all the existing problems in similar solutions are solvable, it is now important to see if it is possible to also solve some of the issues linked with the VCM. Act4 is a reseller, verified by Verra (Verra is a registry in the VCM). This means that all the issues regarding double counting of credits are not solvable at the act4 level, as they are dealt with by the Verra registry (as we previously discussed). Sure enough, the blockchain technology can ensure that a credit is sold only once by act4, meaning that act4 is technically unable to behave in bad faith. Practically it means that the customer does not need to have any kind of trust in act4, but should rather have trust in the Verra registry. Unluckily, due to the nature of act4, the only real pain-point that can be solved by adopting blockchain is the verifiability of the source of the credit. Since act4 is registered in the Verra registry as a reseller, a customer can assume that all credits supplied by act4 are unique and backed by some real and functional offsetting project. If the blockchain technology is implemented, any credit bought from act4 would be easily identifiable and with the aforementioned premise that act4 is part of the Verra registry, that would ultimately mean that the credit is 100% valid and verified. The "checking the source" process would then only take seconds, and it would be easy to demonstrate that a specific customer has in fact bought credits from act4 and has hence been offsetting some emissions. This is a rather small accomplishment, but an accomplishment nonetheless.

Gathering all the considerations, a blockchain solution is rather clear. Act4 is the intermediary between offsetting projects and customers and as such will generate specific metadata and NFTs in a quantity equal to the number of offset credits supplied by a specific project. These NFTs will be available for customers to buy. The price will be set in stable-coins and the NFT will be determined to be non-transferable, in order to avoid fluctuations in price. Once a purchase is made, the bought NFT will be minted by NWG, into the customer's wallet (in the blockchain and cryptocurrencies world, a "wallet" is a software that allows users to store their funds). Such NFT will be stored on the blockchain and hold information about the underlying project (such as location, nature of the project, timestamp). After this procedure is complete, the customer will be the rightful owner of the NFT representing a specific offsetting project and he will be able to demonstrate his ownership very easily, as well as demonstrating that the credit has been bought from a verified reseller (act4).

This point is specific to act4, as this document is a feasibility study with specific regards to this company. However some considerations and thoughts regarding the implementation of a similar solution at "higher levels" that would solve more problems will be presented in the Conclusions section.

3.4 Picking the proper Blockchain Protocol

As discussed in the "Methods and Materials" section as well as in the previous point, an educated choice about the underlying technology must be made. The specific criterion have already been explained. Note that since the solution will indeed require NFTs, that filter will be applied as well. The initial sample of 20 decentralized protocols consists of the following blockchains:

> BTC (Bitcoin), ETH (Ethereum), XMR (Monero), KDA (Kadena), VET (VeChain), XRP (Ripple), LTC (Litecoin), XLM (Stellar), NEO (Neo), QTUM (Qtum), WAVES (Waves), ADA (Cardano), XTS (Tezos), EOS (EOSIO), AVAX (Avalanche), FTM (Fantom), ALGO (Algorand), TRX (Tron), SOL (Solana) and DOT (Polkadot)

Now that the initial sample is determined, the filtering process can start. This first section will expose the results linked with the feasible case scenario, taking into account all the constraints and filters.

3.4.1 Feasible Case

As previously discussed, the first requirement is for the blockchain to support smart contracts. Among the sample, the 15 following protocols satisfy this criterion:

> ETH (Ethereum), KDA (Kadena), VET (VeChain), NEO (Neo), QTUM (Qtum), WAVES (Waves), ADA (Cardano), XTS (Tezos), EOS (EOSIO), AVAX (Avalanche), FTM (Fantom), ALGO (Algorand), TRX (Tron), SOL (Solana) and DOT (Polkadot).

The next filter is the support of Solidity or another mainstream coding language (such as python, C++, Java, and similars). The following 11 blockchains satisfy this condition:

> ETH (Ethereum) native language is solidity, VET (VeChain) supports Solidity, NEO (Neo) uses C#, QTUM (Qtum) supports python, EOS (EOSIO) uses C++, AVAX (Avalanche) supports solidity, FTM (Fantom) supports solidity, ALGO (Algorand) supports python, TRX (Tron) uses Java, SOL (Solana) supports C++ and DOT (Polkadot) supports C++.

The 4 discarded options are as follows:

> KDA (Kadena) uses pact, WAVES (waves) uses RIDE, ADA (Cardano) uses Haskell and XTS (Tezos) uses Michelson.

Following, the protocols that have no intuitive way of implementing NFTs are discarded. In this case, only QTUM (Qtum) does not allow for easily implementing NFTs and will hence be the only discarded protocol in this step.

Among the 10 possibilities, the 5 most sustainable ones will be picked. As discussed in the Methods and Materials section, a specific number for consumptions is not always available. The consensus protocol will hence be taken into account to make an educated guess. The blockchain technologies and relative consensus algorithms are as follows:

> ETH (Ethereum) uses Proof of Work (PoW), VET (VeChain) uses Proof of Authority (PoA), NEO (neo) uses delegated Byzantine Fault Tolerance (dBTF), EOS (EOSIO) uses Delegated Proof of Stake (DPoS), FTM (fantom) uses asynchronous Byzantine Fault Tolerance (aBFT), ALGO (Algorand) uses Proof of Stake (PoS), TRX (Tron) uses Delegated Proof of Stake (DPoS) and DOT (Polkadot) uses Nominated Proof of Stake (NPoS) which is a variant of Proof of Stake (PoS).

Note that AVAX (Avalanche) developed their own consensus algorithm and little documentation regarding the consumptions is available. SOL (Solana) is in a similar situation, as it also uses a consensus protocol that is not investigated in the cited documents. Unluckily, no trustworthy source has been found to discuss the consumptions of these two blockchains. For this reason, these blockchains will be discarded.

A second note regards the Algorand blockchain. As stated, ALGO makes use of the Proof of Stake consensus algorithm. As visible in the cited documents, PoS is not necessarily the most sustainable consensus protocol, Algorand developers have however claimed to have developed a carbon-neutral platform, meaning that the net-emissions are zero. This information is directly available on their website and is hence considered to be trustworthy (Algorand 2022). Citing from said website, they achieve net-zero emissions by: Having designed a highly energy efficient network from the start, partnering with organizations focused on sustainable use cases and offsetting any small emission gaps. Given these reasons, the Algorand blockchain is considered to be the most sustainable protocol and will hence be considered for the next step.

The following blockchains are the five most sustainable from a consensus protocol point of view:

> VET (VeChain), NEO (Neo), FTM (fantom), TRX (Tron), and ALGO (Algorand) is added to the list, as previously explained.

To make a final selection, the transaction cost is evaluated. As stated, if an official source is not available an average of the last 20 transactions cost will be made. The five protocols scored as follows:

> ALGO (Algorand) average per-transaction cost evaluates at 0.0010 ALGO, equivalent to 0.000763 USD at the current price of 0.762998 USD/ALGO (Yahoo Finance 2022).

> VET (VeChain) average per-transaction cost evaluates at 1.7690 VTHO (VeChain transaction fee token is VTHO), equivalent to 0.004953 USD at the current price of 0.002800 USD/VTHO (Yahoo Finance 2022).

> NEO (Neo) per-transaction price is estimated to be 0.0010 GAS (see the Methods and Materials section), equivalent to 0.003360 USD at the current price of 3.360000 USD/GAS (CoinMarketCap 2022).

> TRX (Tron) average per-transaction cost evaluates at 4.563332 TRX, equivalent to 0.386446 USD at the current price of 0.084685 USD/TRX (Yahoo Finance 2022).

> FTM (Fantom) average per-transaction cost evaluates at 0.060700 FTM, equivalent to 0.039482 USD at the current price of 0.650452 USD/FTM (Yahoo Finance 2022).

The chosen protocol for the feasible blockchain solution should then be the Algorand protocol, since it offers all the needed tools and is a sustainable and cheap solution.

3.4.2 Ideal Case

To have a more general assessment that could be valuable outside of the act4 scope, an ideal case is considered as well. As discussed in the Method and Materials section, this consideration will be made similarly to the feasible scenario, but will not take into account the constraints given by the current act4 possibilities. Since this process has already been described, the following part will only expose the results.

The investigation can start from the sample of blockchains that support smart contracts, since that filter is common to both cases. As shown in 4.1, the following protocols are taken into account:

> ETH (Ethereum), KDA (Kadena), VET (VeChain), NEO (Neo), QTUM (Qtum), WAVES (Waves), ADA (Cardano), XTS (Tezos), EOS (EOSIO), AVAX (Avalanche), FTM (Fantom), ALGO (Algorand), TRX (Tron), SOL (Solana) and DOT (Polkadot).

The next filter for the ideal case, is the sustainability of the protocol, since technical constraints are not important in this instance. The 15 protocols and their consensus mechanisms are as follows:

> ETH (Ethereum) uses Proof of Work (PoW), VET (VeChain) uses Proof of Authority (PoA), NEO (neo) uses delegated Byzantine Fault Tolerance (dBTF), EOS (EOSIO) uses Delegated Proof of Stake (DPoS), FTM (fantom) uses asynchronous Byzantine Fault Tolerance (aBFT), ALGO (Algorand) uses Proof of Stake (PoS), TRX (Tron) uses Delegated Proof of Stake (DPoS), DOT (Polkadot) uses Nominated Proof of Stake (NPoS) which is a variant of Proof of Stake (PoS), KDA (Kadena) uses Proof of Work, WAVES (waves) uses Leased Proof of Stake (LPoS), ADA (Cardano) uses Proof of Stake (PoS), XTS (Tezos) uses Proof of Stake (PoS) and QTUM (Qtum) uses Proof of Stake (PoS).

Similarly to the feasible case, AVAX (Avalanche) and SOL (Solana) are discarded due to the lack of documentation.

The 5 most sustainable solutions are then the following:

> VET (VeChain), NEO (Neo), FTM (fantom), TRX (Tron), and ALGO (Algorand).

Interestingly enough, the top 5 of the most sustainable protocols remain unchanged from the feasible case. This directly means that the last filter yields the same result as well.

As a result of this process, it can be stated that the best blockchain protocol for this application (tokenization of Carbon Credits as NFTs) is currently ALGO (Algorand), independently from the size and means of the organization that plans on implementing the solution. This result is not only surprising, but from the act4 point of view relieving as well, as it means that a competitive solution can potentially be created.

4 Conclusions

This section will briefly discuss the findings and overall accomplishments, as well as point out future works and discuss a highly technological and ”futuristic” scenario.

4.1 Conclusions

The VCM flaws have to be addressed and solved as soon as possible, as the VCM is a fundamental part of the green transition. The assumption made in the beginning of the document was that introducing a blockchain solution can solve some of the problems linked with the VCM, and this resulted to be correct as such a solution can resolve all kind of double accounting problems, when applied to the right level. What could instead be easily achieved and implemented by act4, is a blockchain solution that only solves the ease of verification of the origin of credits issue. This solution would also give act4 and NWG the possibility of entering the virtual world and/or metaverse in due time, but this point is outside of the VCM scope. What this means is that implementing a blockchain solution in act4’s particular instance might have more value regarding future business possibilities rather than from a “solving the Voluntary Carbon Market” point of view. Nonetheless, a blockchain solution is currently possible and feasible, and if implemented at the Registry level it would in fact solve all double counting problems. This research gave an overview on the architecture and features of a currently possible blockchain solution, appliable at any level of the VCM.

4.2 Theoretical Contribution

The blockchain technology and consequently the cryptocurrencies world has been in the spotlight for some years. At the current stage, the main effect (without giving any connotation) and use case is speculation. However, more and more projects that are trying to seize the real power of the blockchain technology are being developed on a daily basis. This feasibility study contributes to the general scope of “Innovation through new and upcoming technologies”, trying to capture the true benefits of the blockchain technology and using that power for a meaningful purpose. This document can be utilized as a theory guide or framework to build a blockchain solution for the VCM, since every step is justified and weighted.

4.3 Future Work and Limitations

If a solution was to be implemented by a registry, this study would not suffice to have a working product. To have a fully working implementation, there is the need for the actual software to be working, meaning that a further study or learning of the blockchain technology from a more technical point of view would be needed. On top of that, there are some limitations that have not been addressed. Particularly, the solution is technically possible but a business cannot simply develop something because it is feasible from a technical point of view. Some further investigation regarding the business model would be required, as well as an in-depth research on the legality of such a solution. This last point is perhaps the one that requires the most effort, as cryptocurrencies and blockchain technology are rather new in age terms, and can hence sometimes be in a grey legal area. In order to make sure that the solution complies with regional, national and international laws, a team of experts should examine the project and conduct some research.

4.4 Discussion

Given the nature of the document, only a feasible solution has been presented. However, to conclude, I will discuss a more technological and idealistic scenario that a mix of the blockchain technology and some hardware would allow for. This solution is not thoroughly investigated and notions will hence be only approximate. This solution would also require an initial investment and a team of skilled software developers.

What could potentially be possible, is to build an oracle. An oracle in the blockchain space is a piece of hardware (or software) responsible for carrying information from outside the blockchain to inside the blockchain. This is not possible to do from the blockchain itself as it needs to be a deterministic system in order to work. A transaction needs exactly the same inputs to be validated. If a transaction depends on off-chain data, such as temperature in a specific place or the price of a stock, it would be impossible to validate that transaction as the transaction output would vary each instant. Due to this issue, blockchains do not automatic allow for API calls and similar. This type of data is however very important and not being able to access it, drastically limits the possibilities for projects. Oracles are responsible for entering data into the blockchain, and they do so through an external transaction so that the data does not change each instant. There is now a second issue, which is the centrality of oracles, this is often referred to as “the oracle problem” (Sheldon, 2021). To make an intuitive example, if a betting smart-contract is developed, where people can bet on sport events, how should the result of a particular event be declared? If the creator of the contract has to manually input the result, that would basically mean that the users would have to trust the creator not to behave in bad faith or not to make a mistake. This ultimately defies the appeal of the trustlessness linked with the blockchain. How this problem is solved, is that instead of a person directly declaring the winner of a specific competition, an autonomous decentralized piece of software will do that instead. When a sport event finishes, this piece of software will take the result from a number of sources (to avoid mistakes) and then automatically give the result and pay off the winners. This piece of software would be called “decentralized oracle”.

What would then be possible, is to build an oracle that is responsible for minting VCM tokens only when the GHG counterpart has actually been removed. This could be done for example with LIDAR technology, monitoring reforestation, or with CO_2 sensors, monitoring the level of carbon dioxide in a certain area, and so on. The possibilities are virtually limitless and everything that can be verified via some existing hardware, can be made into an oracle. If this solution was to be developed, it would not only solve every double counting problem, but it would also autonomously guarantee the validity of a certain credit (and consequently of the token representation of that credit). The whole complex infrastructure of Registries, Standards, resellers, and so on, would ultimately not be needed anymore.

5 Bibliography and Sources

Bada, A. O., Damianou, A., Angelopoulos, C. M., & Katos, V. (2021). Towards a Green Blockchain: A Review of Consensus Mechanisms and their Energy Consumption. 2021 17th International Conference on Distributed Computing in Sensor Systems (DCOSS), September, 503–511. https://doi.org/10.1109/DCOSS52077.2021.00083

Cercarbono. (2021). Procedures for issuance and withdrawal of Carboncer and double accounting policies.

ClimateWorks Foundation. (2019). Guidelines on Avoiding Double Counting for the Carbon Offsetting and Reduction Scheme for About These (Issue June).

European Commission, On industrial emissions (integrated pollution prevention and control), Pub. L. No. L 334/17 (2010).

Drescher, D. (2017). Blockchain Basics (G. Todd, M. Susan, B. Laura, F. Rita, & B. Mary (eds.)). Apress Media. https://doi.org/10.1007/978-1-4842-2604-9

Ene, C. (2020). Smart contracts - the new form of the legal agreements. Proceedings of the International Conference on Business Excellence, 14(1), 1206–1210. https://doi.org/10.2478/picbe-2020-0113

FCLTGlobal. (2022). Unpacking the Value of Corporate Net Zero Commitments.

Gold Standard Afforestation / Reforestation (A / R) GHG Emissions Reduction & Sequestration Methodology 2017, last accessed 21 May 2022 <https://globalgoals.goldstandard.org/403-luf-ar-methodology-ghgs-emission-reduction-and-sequestration-methodology/>

Guadamuz, A. (2021). The Treachery of Images: Non-fungible tokens and copyright. SSRN Electronic Journal, 16(12), 1367–1385. https://doi.org/10.2139/ssrn.3905452

Hughes, L. (2000). Biological consequences of global warming: Is the signal already apparent? Trends in Ecology and Evolution, 15(2), 56–61. https://doi.org/10.1016/S0169-5347(99)01764-4

Jenni, K. E. (1997). Explaining the " Identifiable Victim Effect ." Journal of Risk and Uncertainty, 14, 235–257.

Kollmuss, A. (2010). Climate Action Reserve. In Handbook of Carbon Offset Programs (Issue 1, pp. 142–147). Earthscan.

Poudyal, N. C., Siry, J. P., & Bowker, J. M. (2012). Stakeholders' engagement in promoting sustainable development: Businesses and urban forest carbon. Business Strategy and the Environment, 21(3), 157–169. https://doi.org/10.1002/bse.724

Sheldon, M. D. (2021). Auditing the Blockchain Oracle Problem. JOURNAL OF INFORMATION SYSTEMS, 35(1), 121–133. https://doi.org/10.2308/ISYS-19-049

Trove Research. (2021). Future Demand, Supply and Prices for Voluntary Carbon Credits-Keeping the Balance. June, 0–50. https://trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf

European Union, Establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, Pub. L. No. L 275/32, 32 (2003).

Xiong, H., Chen, M., Wu, C., Zhao, Y., & Yi, W. (2022). Research on Progress of Blockchain Consensus Algorithm: A Review on Recent Progress of Blockchain Consensus Algorithms. Future Internet, 14(2). https://doi.org/10.3390/fi14020047

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. Proceedings - 2017 IEEE 6th International Congress on Big Data, BigData Congress 2017, 557–564. https://doi.org/10.1109/BigDataCongress.2017.85

Hafner, M., & Raimondi, P. P. (2021). Priorities and challenges of the EU energy transition: From the European Green Package to the new Green Deal. Russian Journal of Economics, 6(4), 374–389. https://doi.org/10.32609/J.RUJE.6.55375

Lovell, H. C. (2010). Governing the carbon offset market. 353–362. https://doi.org/10.1002/wcc.43

Lovell, H., & Liverman, D. (2010). Understanding carbon offset technologies. New Political Economy, 15(2), 255–273. https://doi.org/10.1080/13563460903548699

Algorand 2022, last accessed 8 May 2022, <https://www.algorand.com/about/sustainability>

NeoDocsBulider 2021, last accessed 9 May 2022, <https://docs.neo.org/v2/docs/en-us/tooldev/concept/charging_model.html>

NeoDocsBulider 2021, last accessed 9 May 2022, <https://docs.neo.org/v2/docs/en-us/sc/fees.html>

Yahoo Finance 2022, Yahoo, last accessed 8 May 2022 <https://finance.yahoo.com/quote/ALGO-USD/>

Yahoo Finance 2022, Yahoo, last accessed 8 May 2022 <https://finance.yahoo.com/quote/VTHO-USD/>

Yahoo Finance 2022, Yahoo, last accessed 9 May 2022 <https://finance.yahoo.com/quote/FTM-USD/>

Yahoo Finance 2022, Yahoo, last accessed 9 May 2022 <https://finance.yahoo.com/quote/TRX-USD/>

EcoRegistry 2019, asocarbono, climate chain coalition, International Emissions Trading Association, last accessed 20 May 2022 <https://www.ecoregistry.io/>

CoinMarketCap 2022, last accessed 9 May 2022 <https://coinmarketcap.com/currencies/gas/>

CoinMarketCap 2022, last accessed 10 May 2022 <https://coinmarketcap.com/currencies/toucan-protocol-base-carbon-tonne/>

CoinMarketCap 2022, last accessed 10 May 2022 <https://coinmarketcap.com/currencies/moss-carbon-credit/>

CoinMarketCap 2022, last accessed 10 May 2022 <https://coinmarketcap.com/currencies/carbon-utility-token/>

CryptoMarketPool 2022, last accessed 19 May 2022 <https://cryptomarketpool.com/lock-a-token-so-it-can-not-be-transferred/>

VCMPrimer 2022, Climate Focus, last accessed 21 May 2022 <https://vcmprimer.org/chapter-7-what-is-the-role-of-carbon-standards-in-the-voluntary-carbon-market/>

United Nations Framework Convention on Climate Change 2022, last accessed 19 May 2022 <https://unfccc.int/>

Tron Block Explorer 2022, last accessed 9 May 2022 <https://trx.tokenview.com/en/>

Fantom Block Explorer 2022, last accessed 9 May 2022 <https://ftmscan.com/>

VeChain Block Explorer 2022, last accessed 8 May 2022 <https://explore.vechain.org/>

Algorand Block Explorer 2022, last accessed 8 May 2022 <https://algoexplorer.io/>

6 Appendix

Following is the list of all transactions and blocks taken into consideration for calculating the average transaction cost:

Algorand blockchain:
All transactions included in block: 20880889
Transactions list:
Q2A53US76JASWUZLGCXQZCKWV3HHEZSIVLJNW7Q3HCCFIGW4XQQQ,
BHMD3ORIC7VXBB7KC62DLPZOVDFVZ4CKQQ3QICO5SGS3SSIO3JXQ,
HLII4JLYEAKEBT55ENAKOEORIQIELWPTDAOQ2HN5WXA5LJ47VLDA,
3XEYZAZCPV76GITNYNJQZBFVLWOOCTKGRJ4EOL6TMFKJSXJ6Z2WQ,
FHCM62PLRMTZ7OYP7UIJDXLPGJFJG2VI6EARAESM5LYU3Y7LP6JQ,
NFG6JH2CCAQ3GXYMXDOHF7DR5XRSQMOC7XOL3NXKWF33FC6OF7AQ,
5WZEQVW2T6PJ72WOOERBFYZVYMRSPPIOTCDCQTAO5WYB5YHD2YPA,
4H24YPTDOKINKWOEAFMR5DQFAHN7AK26G3NBF7VWFKF2GMD6SYVA,
NZNO7GYEAIKCRGPMA6YY2MO2NNZXXVPNOTE6YOKJVLAYX3LIDOCQ,
UP5LGRTSQAXS3XXLAMNHOZGCK5XWHL3T3NMZEAWXC4XCX7XBUR2Q,
YP7FUJTJKALCOX34GF25576WCPYB5ZJPXBV2KIBUMY7XTE53EAPA,
4MGJDANQSD5HFWWYVZBDNKLHOPCJTCKFX7XDRL2POGYR6TTVFVNQ,
PIJPPMPDNIPTRMW522ISANG2EIXV2LYWYE5J72XY27HFT43Z5OBA,
CMLVQDLIIIHI7FOWRX5ZNTNAAHOH4AT2VWKTPUU2OMMYUQKU6YFQ,
YO2MFT3FQTA66UALXOURI7NLU2POHA6AROSU6WUFPLRRJWYKNBSA,
EJYKXI2AJ3ENLRGDWRTSL7YCT6PYZ3YD75HZF4CK266FVJ66L26Q,
5QKVH3LTXJKZTILH2XNSELZ77QJA6MC5RVR7B7IHERV2QIEHD2MQ,
DUNF4TYDMGTHCCP673UGUB2GED5FRRLCZ4N67DTCIPSU2L2GJWKQ,
LBUKOQKVIBWZPRFZCMUU3CZNGGODYQHGZSL34PT7YPM4BQTPN2IQ,
4XDUYFBG2RYOMK7DZVJU3LQQAZUOBEH4Y3RMHWRMC4A2K6U3AHEQ

VeChain blockchain:
All transactions included in blocks: 12150222 , 12150221 , 12150220 and 12150219
Transactions list:
0xbc3bfe892475f8b691c1397d93bc1c74d8a43d7ac881876c6c6899a6f2cdf24f,
0xd750e5026f439bf4fe1d2bc9a806d5b94d80161e89b82630030da4c9e6432141,
0x67105968c98c793a9b9356d9e32b024a092af42b04afd96b8a31486cf5bad3ba,
0x87cb765d5ea1a44b13f6872a7e1182ee42ab72cc377ca1e4e513881efa173288,
0x320f34feb9a796bea119eb7672430b25bc7337fcc719e5240120f25fbbc22091,
0x47d4b8f29b1ccc4c163439ca1dfdc06674f0c2bcc654346489302fdf4eba2d39,
0x44f2b95b48c1fd89aa04f20e9ac7f3cca4d8de125a902e3a81c63d3e657d050e,
0x8e21c882ca8c0b8afa1d037d625d59b8224415cb68a76d84e888f6b014bfe0d1,
0x449738fc0cf79e3a629b87a7081fbe2e189eebc8164b8eb1368e5d48579e257d,
0x51f7e090283729d902da88aacc23b5711286b3ba6012e109bfbd3bffc7541c35,
0x8ae67b7e4abbc87eee4a4687e7a0637d2b5aa14a8aeb6c5bf5baa0f2ad00ce53,
0x47e068edd6070850aeedc0e15a988dc566de4d815de45ce41289fea734107b34,
0x2e3b747a100cde69c79072482b3d4e932a3efeca8c6622edb9fed74de59b94fd,
0xcd72f8ea95907e86cce70886a13eb6701436ddf6948489e334a44250fed7b31f,

0x4e1bc11ca5ae184de10cbfad2855084a790e1878196caaee78ce504bc4632d4b,
0x1a0aa7dfa866a52eaef35bf059d0d0e81219b10d56b1abced043a57cb2264312,
0x3a2b993e5ee784234d6ced16f17e0dc89beabbd3abe26ed0f7d5540ef7c164b7,
0xc7aa85e02c87d8121caf5777593443b49891acbaade25d2f8270577600e919c4,
0xfa741cddc4ac9aff78055add71827a684f0031d019eb5d34e337429594e5ee4b,
0xc1514e7e98fe8a8945eb23188ad29e8da3606c435449412ea692d814cf32aebf

Fantom blockchain:
All transactions included in blocks: 37893382, 37893381, 37893380
Transactions list:
0x44260daed708c6cac1cb3afd5ef533d25d8a9e90826713d37f4476b01a0a8e07,
0xfe240c25a38b0a250842443fa5632aaa0c2e2198d1614fa757cbcec0b785e7a7,
0xde2bc3d48b49e54e5ea78e8e79cce333be6532ff5bf74c6c5e52459c294b0983,
0x147b674186f09aa071d9078ac25fc6bf35b5bfdb547a568a71b714f09df18104,
0x923df6ddba15d71725f2946f9361a1d0bb68d14971aa50484921b5c679df8ecc,
0x7ac09c94a158f05fef506e08d65669fba642c90f56e49a1a4291871ce49f4514,
0xd0b28bd8706fbbafb762efbe04c8fa5eef9d7ad95c50ca73590dbe822305d0d2,
0x05d2aef08990ca2c7b20fb8e174e00d4b0676dce07642f6c48e6dd5a2985e5d5,
0xc8287eb0e2ddec228419558004354706206f67e3045deb945b41a5e284498be7,
0x1d2e2b5f308ad9b20a78f8352a8e1fd8d6eeed0077a33b44946d6f6ac5f2e5db,
0x0fdf24f895350365c235b6e4868cc8fc74146a5a62266e1558d64534d477fd15,
0x9d6f57e8719f26f26430ba356c1d329b174b3acc6370384c6d65de6ed7453763,
0xe6d458c8fa89a4ee1747dfa1cf274736777c50bab0e15ca46fad215ca6acd23e,
0x5b5fe8983e3774acf93a7137ccd6a710334d70007213a73a426195e580c093f7,
0x6f364e7e564188c0f57c3b6043d97389e0122c1e4d10c63a34aba1230b4e0cb3,
0x71d3222ff4ed9fa34de252b04c02cb000f9d21b76b445d98118719f14ba05672,
0xa4a82d4811e846920f9fe81d4fb7899eb29cde2acaaf7d8dacf6118f1e5a5660,
0xf55f176278fd04477ea6cf9bb01571db76219877ee2c100034f9a67f49fb587f,
0x3d5c41b51bfc8824b2db3c21e8e1b07e7395e419041a526d60a375a96e08b9c3,
0x16186b984b9c31a32e5048ab63b15c863c6dc17c7169e35e6fbeccd8c7ee8849

Tron blockchain:
All transactions included in block: 40509503
Transactions list:
d337be36eb8d0f6f7de788190880bcb8937a99c52bd4094ab2edfa65e217d051,
b576c7482b9d212cee21dc6823b59fb3da00d4762e17e075ec034a1bbf01b52e,
5551cd6002056979594ebf36be368396647b0a46cf012dad640d2be23f868363,
a91b8bbee4a4a8b794446037fd8715535ff0baeb3b57ed9229f8a54e87c1a0b6,
c41554a80fd8ee47ee6c0a1647404dfb80455cc084de82d452fe9a08de2da915,
66169ab5038c1621e0c07ec0c13c1379a8ec5c075f1efa2a9461a8746c4cbaa5,
1f2edb6e81509ffc872c049d981984a24d55784f4a3c626a561a1359fa145a7b,
72cbb1aaadf4aba07226ba8182c39da372abb82e0f7520cab44b5b0eedacdb24,
b983f1aab94c8aa49379a60123f5b3be8c262c723d119a89947204ad04fb98f0,
6ee522913d7e82205e89dc89c103cdc8278fc0ca99e19295343d404a11cf3d1a,
6c631b969e85baebca41782d1ad8827cb4ce91c7a604da86c45e012f66850717,

c74482a0011521338c8354b9b3a7a3457e8c6a6c9372af4dee41d6c628403293,
539a80e833146208f02787313c2d347ae53faeb414745a4b6758bcc2578707d4,
d8b377eb0b42bf1bcb74a5097a1a0d08f552923b1796807292a4cfa5ac963a7f,
afdfb7da5e1045cdde5219cd567c5485e123e169563db64df3d7a95de2271d21,
23ae9aa2e2d9ff9929924d07dae008c230d17985851be86b4c80b9638a8ec234,
f84e2ff883f12128cb0b3cf7689f3ac79a422418de920cbd56f41e26ced2bffe,
ceb74a913862af06e1d16bf28ee57363988e7f2c7baab2c8a8582463a6115e07,
e26a1042c86eae61899baf5ff6edf48047e7d2fb9c553ed7be35f6990ce845d0,
4b9a6ef42b2dc055fffd74a94ce6d10b2592ddac19b630779882608e9810ddeb