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FACULTY OF ECONOMICS AND ADMINISTRATION

BLOCKCHAIN FOR ENVIRONMENTAL SUSTAINABILITY

Master's thesis

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Abstract

In the past few years, Blockchain has gained immense recognition as an emergent and disruptive technology, it has been implemented in diferent fields with a variety of applications. This thesis focuses on analyzing the effects of its adoptions on environmental sustainability. It assesses the effectiveness of blockchain in resolving environmental sustainability issues. The findings are based in multiple case studies on a sample of six cases selected out of 29 blockchain-based projects. Using secondary data from websites, social networks, white papers, and other publically available sources, the case study includes in-depth evaluations of each analyzed scenario in relation to blockchain application. The outcome of this thesis is a discussion, results implications, limitations and concluding remarks.

Declaration

I certify that I have written the Master's Thesis Blockchain for environmental sustainability by myself under the supervision of Ahad Zareravasan and I have listed all the literature and other sources in accordance with legal regulations, Masaryk University internal regulations, and the internal procedural deeds of Masaryk University and the Faculty of Economics and Administration.

Brno, ...

MENDOZA TOVAR, EUTIMIO

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1 Introduction

1.1 Blockchain

In the last decade, Blockchain technology has greatly increased its popularity worldwide. It was conceptualized in 2008 by a person (or group of people) known as Satoshi Nakamoto, released in the white paper. In the white paper, he explained how blockchain technology was designed to enhance digital trust given the decentralization characteristic, and as a result, nobody would ever be in control of anything. Decentralization is the core concept of blockchain; it eliminates the necessity for a centralized network management authority. Using a consensus technique, the peers are more than capable of managing and validating the transactions. In short, blockchain is a distributed database that is shared among the nodes of a computer network. In this database, blockchain stores in-formation electronically in digital form. Blockchains are well known for their critical role in keeping a secure and decentralized record of transactions in cryptocurrency systems such as Bitcoin.

The evolution of Blockchain technology has increased massively in the last few years. This unique characteristic of decentralization, among others, that blockchain technology offers is attracting other business sectors. Blockchain applications go far beyond just the cryptocurrency system, such as supply chain, healthcare, banking and finance, govern-ment, real estate, energy, and many other sectors. Currently, there are a large number of projects working in these sectors aiming to improve their processes by adopting block-chain technology.

1.2 Sustainability

Similarly, as blockchain, sustainability must be one of the words more used in the last decade among the business sectors. Sustainability refers to the ability of something to maintain or sustain itself over time. It has become quite popular mostly due to climate change, shortage of natural resources, poverty, and several more factors. Thus, in the last decade, a diverse network of actors has been built, such as organizations (NGOs), pro-jects, and institutions in the name of sustainability to tackle these issues. The United Na-tions (UN) is the world's largest, most well-known, most widely represented, and most powerful intergovernmental organization and the place where the world's nations can gather together, discuss common problems and find shared solutions. In September 2015, the UN adopted 17 sustainable development goals (SDGs) by 2030.

1.2.1 Sustainable development goals (SDGs)

The SDGs are an integral part of the 2030 Agenda for Sustainable Development, which aims at fostering a more sustainable future. The SDGs are extremely important as they unify nations to counteract global problems. The 17 SDGs adopted by 2030 are no pov-erty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions and partnerships for the goals.

1.2.2 Environmental sustainability

As the global population rapidly grows and we begin to see the negative impacts of excessive energy use, deforestation, immoderate use of natural resources, and industrial growth, we must prevent further damage. Over the years, the majority of businesses and governments were not paying adequate attention to the adverse social and environmental impacts posed by them. Most of the time, profitability outweighs sustainability. In response to increased worldwide attention on the overall conditions of natural re-sources and the environment, there have emerged sustainable projects, new technologies, organizations, and businesses are moving towards sustainability. It is our responsibility to guarantee that future generations have safe places to live and to minimize the damaging impact on our earth's biodiverse ecosystems. Environmental sustainability seeks to tackle these environmental issues that the world is facing. It aims to improve the quality of human life without putting unnecessary strain on the earth's supporting ecosystems. It is about creating an equilibrium between consumerist human culture and the living world. We can do this by living in a way that does not waste or unnecessarily deplete natural resources.

1.3 Research Purpose

The purpose of this thesis is to identify the role of blockchain projects that seek environmental sustainability as part of their business model and analyse them. These pro-jects will vary in their industry and are meant to solve an environmental issue. Despite the large number of projects launched in recent years, their progress and survival in the market are uncertain. The purpose of information obtained should be of use for academia and practitioners in any field.
The following main question is based on the objectives already defined:

- What is the potential of Blockchain technology in fulfilling sustainability goals?

The approach to answering this question will be as an exploratory case study research combined with existing implementation cases and papers on environmental sustainability in blockchain technology. The main focus of this research will be on the existing pro-jects implemented with considerable legitimacy.

1.4 Research structure

The structure of this thesis will be as follow. Firstly, the literature review is presented to provide general knowledge of the topic and make a better understanding for the analysis afterward, and this chapter is the only theoretical part of this paper. The next chapter is the presentation and classification of the projects to analyse. The aim of this chapter is to provide brief information of the projects. The third chapter is the analysis and evaluation of the projects selected. And finally, the last chapter is the conclusion with the main contributions of the study.

2 Literature Review

2.1 Blockchain Basis

In 1982 in his dissertation at Berkeley, David Chaum first proposed a distributed computer system governed by technology that could process private transactions while achieving privacy by untrusted parties which could operate and maintain the system. The system was a mix of physical vaults, cryptographic encryption, and his method to achieve consensus. Even though his work was vital for developing blockchain technology, it remained unnoticed for several years (Sherman, Javani, Zhang, & Golaszewski, 2019). It was until 2008, after the financial crisis, Santoshi Nakamoto, maybe the most famous entity in the crypto community, introduced Bitcoin in his paper "Bitcoin: A peer-to-peer electronic cash system." Santoshi describes Bitcoin as electronic cash where two parties can make a financial transaction without the need of a bank or financial institution working as the trust entity (Nakamoto, 2009). This was the first use case of blockchain technology and perhaps the start of a revolution, a disruption of the modern financial system, and the first time the blockchain term appeared.
A blockchain is a complex algorithm that uses cryptography and a consensus model to make reliable and secure transactions between parties. Created to be processed by computers instead of humans to reduce points of failure (Kruglova & Dolbezhkin, 2018). (Michael Casey, Jonah Crane & Narula, 2018) described in their report the following characteristics that blockchains have in common:
• A ledger with the information of the transactions is shared and worked among different parties inside the network, which may not trust each other, and none of the entities have complete control over the ledger in the blockchain
• The transaction ledger grows with more transactions added, and the objective is to maintain a single source of truth to prevent changes in past transactions. New transactions are added to the blockchain once most of the members agree on them using consensus methods
• The transactions are digitally signed to indicate the activity they want to execute on the blockchain, for example: creating a new record on the ledger or modifying data.

2.2 Consensus Method

Blockchains present a solution to the distributed consensus, a problem found in computer networks when a participant could introduce false information that can compromise the security and integrity of the information in the network. Currently, we rely on big companies that develop algorithms to store important information. Amazon created AWS as one of the most extensive cloud computing systems, with an army of data centers worldwide, with the highest security standards globally. We can also find many other big players such as Google, Microsoft, and Facebook. These companies invest in creating systems with the most robust safety properties, but they are still centralized entities that control data access. One of the main problems they are trying to solve is the Byzantine Generals Problems, first described by (Lamport L. 1982). An agreement problem is based on an analogy of a city surrounded by Byzantine troops, which are geographically separated. The only source of communication with each other is through messengers, and the main goal of the generals is to decide whether to attack the city or not; if they disagree, they may not conquer the city. The story presents some challenges, including generals who are traitors trying to send false information to the other generals. The messengers could also be intercepted by the enemy interrupting the delivery of the messages or replaced by faulty messages, making it hard for loyal generals to agree on a joint decision. The problem in a computer distributed network represents the generals as computers, messengers as data sent through the network, and traitors as malicious or faulty computers. (Fedotova & Veltri, 2006) describes the problems that the byzantine failure can cause in computer networks:

- Failure trying to pass to the next step in the algorithm
- Execution of a different step in the algorithm other than the one expected
- The inability to execute the current algorithm

In a blockchain network, the computers must agree on a ledger of transactions shared between all the parties involved. Blockchains have a high tolerance for Byzantine faults and achieve this by using different consensus methods among participants. The final objective of the consensus model is to achieve consistency of the information inside the blockchain among participants. Two methods have gained popularity in Blockchain projects, Proof of Work (PoW) and Proof of Stake (PoS).

2.3 Proof of Work (PoW)

Based on Adam's Back's Hashcards (Back, 2002) and first presented in the Bitcoin white-paper (Nakamoto, 2009), Proof of Work is the consensus model used in Bitcoin. The consensus model requires three entities: miners, nodes, and users. The miners are self-interested participants in the network that are responsible for mining new blocks. One block consists of a set of transactions intended to be added to the blockchain. The miners collect transactions and compete to create new blocks by solving complex computational problems. Once a miner finds the solution, he broadcasts it along with the new block among participants, and the miner will receive a reward in Bitcoin as an incentive to keep the network secure. An incentive is necessary because miners incur costs for specialized hardware equipment to solve computational problems. The system has a difficulty level algorithm that adjusts depending on the number of miners participating. If the number of miners increases, the computational problem to solve increases as well in difficulty. The same principle applies if the number of miners decreases, the difficulty level will decrease; the end goal is to incentivize computer power to ensure the network is secure while reducing the difficulty in case miners leave the network.
Back in the early days of Bitcoin, in 2019, it was possible to mine a new block by using a simple computer' or a server's power. Currently, companies use large buildings full of devices specialized for this purpose. For example, Core Scientific, one of the biggest miner farms in the USA, plans to file public with a 4B USD (Forbes, 2021). The second entity in PoW is a group of operating computer nodes that observe and validate the Bitcoin blockchain (Michael Casey, Jonah Crane & Narula, 2018). These nodes do not receive any bitcoin as a reward. However, miners and companies like Tesla run their nodes to ensure that the transactions received exist in the blockchain. The last actor in the PoW is the end-users; they send and receive Bitcoin from other parties P2P by submitting transactions to the network. These transactions will come with a fee distributed to the miners once they add the block to the blockchain. It is essential to understand that this fee is a certain amount, approximately 2.2 dollars by September 2021, that will not depend on the amount of Bitcoin sent through the network.
The main challenge that this type of consensus model presents is the use of extensive energy, the consensus method used in Bitcoin has a particularity. Every four years, a "Halving" event will occur; this means that for every halving, the amount of bitcoin received by miners who solve the computational problems is reduced by 50% (Nakamoto, 2009). The idea is that if there is a constant demand for Bitcoin while the supply diminishes over time, the price of the asset will increase and incentivize miners to keep mining because the profits will not fall. In recent years an increase in Bitcoin's price, 64,863 USD in April 2021, led to more mining operations which have expanded among different regions worldwide. The rise of mining operations is good for the security of Bitcoin because it adds less probability that miners can collude to make a 51% attack making the network insecure.

The dark side of this new technology is the amount of electricity used by miners. The energy consumed has reached a peak that is not environmentally sustainable; according to the University of Cambridge Bitcoin Electricity Consumption Index, the Bitcoin network consumes approximately 80 terawatt-hours, similar to what Washington State or a small country like Finland consumes annually (Times, 2020). For years, most mining operations took place in China, a country with plenty of cheap energy sources, primarily coal plants. With the introduction of climate goals and blackouts around the country, the government of China has announced new crackdowns on cryptocurrencies that led to an exodus of companies looking for other sources of energy outside the country. These events reduced China's dominance of hash from 75% to 46% from September 2019 to April 2021, according to data from (Cambridge, 2021). The reduction of China's participation impacts the network in the short term. On the other side, this reduction makes the Bitcoin network more secure and decentralized because some mining operations moved to other countries. The spread of mining operations across the globe and the uses of renewable energies are also cryptocurrency opportunities. In the Oil industry, some wells flare due to the methane gas extracted as a waste; in remote areas, drillers have no pipelines to sell the gas, and the easiest way to get rid of it is to burn or vent the residual gas. Some companies worldwide are using the flare to power Bitcoin mining, which otherwise will be a waste. The same principle applies when renewable plants reach a peak in production. Instead of storing that energy in costly batteries, the power could power crypto mining companies; this does not solve the problem of the high-intensity use of energy by Bitcoin but accelerates the pace of use of renewable energies by the network.

2.4 Proof of Work (PoS)

The second most famous consensus method was created to address one of the challenges that PoW experiences, intensive energy usage. In Proof-of-Stake (PoS), validators, which make the same work as the miners in PoW, collect transactions and submit the blocks so that the nodes can agree on the new blocks added to the blockchain. However, they do not compete for the right to submit a block into the blockchain compared to PoW (Ethereum-Foundation, 2021b). In order to be a validator, an entity or user must stake a certain number of the native cryptocurrency in "staking pools." The staking pools reward stakers with a small fee paid in the native cryptocurrency, similar to an interest rate in investment accounts. PoS blockchains foment the creation of several staking pools to achieve more decentralization. In this consensus model, the algorithm chooses a validator randomly to create the new blocks; the more cryptocurrency staked, the more chances to create the next

block. The rest of the nodes validate the proposed blocks. Both parties will receive a reward fee in the native cryptocurrency of the network.
The following characteristics are present in a Proof-of-Stake:
• Better use of energy since just the chosen validator works the computational problem provided by the algorithm
• Decentralization, the system should attract more nodes in the network, with theoretically makes it more resilient to attacks
• Lower barriers for entry, the less intensive computational power needed, and the minimum staking number
• Higher scalability already proven by some blockchain projects
(Sunny King, 2012) introduced the first use case of PoS in the blockchain implementation Peercoin as a hybrid model using PoW. Later the first project just using PoS as the consensus model was Nxt in 2013, and since then, many projects have appeared in the blockchain ecosystem.
Today relevant PoS projects include Cardano, Polkadot, Solana, AVAX, and the list is growing every month.
In recent years the number of PoS blockchains has increased (F Irresberger et al., 2020), showing that more than 50 projects have been deployed since 2015 and more PoS projects are used currently compared to PoW blockchains. The rise of decentralized applications (DApps) related to finance has attracted a large customer base. Some of the applications are decentralized exchanges such as Uniswap, a project running in the Ethereum blockchain, or lending protocols such as AAVE, a blockchain platform in which users can borrow tokens instantly with collateral in cryptocurrencies.
The second most famous blockchain implementation, Ethereum, went live in 2015, a crowdfunded project led by Vitalik Bulerin at the Ethereum Foundation (Ethereum-Foundation, 2015). The project started with a PoW consensus model. Back then, PoW was the standard for blockchain projects, and such decisions limited scalability; thus, the foundation decided to develop Ethereum 2.0. A transition to PoS, which aims to increase the number of transactions per second that the protocol can handle, currently, the roadmap is targeting Q3 2022 to make the transition to PoS. The goal of PoS is to reduce the use of energy and add scalability. Figure 1 shows a relative energy consumption per transaction between Bitcoin, current Ethereum (PoW), and upcoming Ethereum 2.0 (PoS).

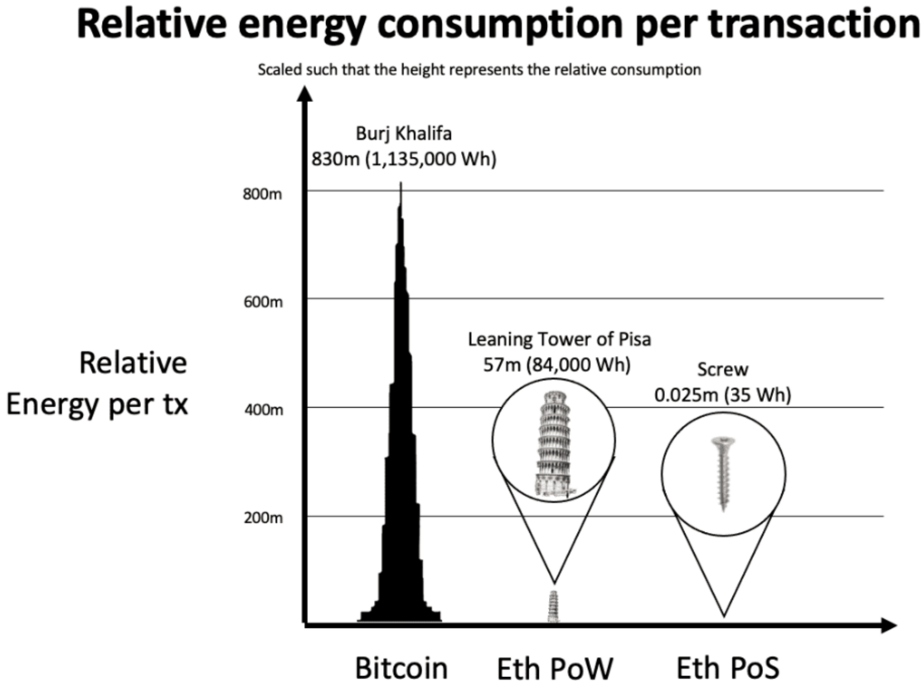


Figure 1: Data provided by Ethereum-Foundation, 2022 - (https://ethereum.org/en/energy-consumption/), Estimate of PoW energy consumption per tx used in figure based on May 2021 data, at time of writing the same source suggested up to 175.56 Kwh

The proposal is a complex architecture called "shard chains," separate blockchains on top of Ethereum 2.0 will need their validators to process their blocks. The upgrade proposes 64 shard chains with an extra beacon chain to coordinate information to the Ethereum principal blockchain. (Ethereum-Foundation, 2022) explains that this upgrade will allow Ethereum 2.0 to increase the theoretical number of transactions per second or TPS from the actual 20 to 100,000. To have a notion of the potential, VISA currently handles 1,700, claiming a maximum capacity of 64,000 TPS theoretically (VISA, 2018).
In principle, this approach of blockchains on top of other blockchains seems to be promising, a new type of architecture completely innovative, which will lead to challenges and projects proposing new ideas. What is interesting, back in 2017, is the fact that nobody expected blockchains to be able to scale fast enough. In 2022, we have projects with live use cases that challenge business models provided by traditional financial institutions, supply chain processes, secure sharing of medical data, etc. This is partly because PoS blockchains let applications scale to millions of users without financial or computational costs. In figure 2, we can see how some new players addressed scalability issues. It is only

a matter of time until blockchain technologies gain mass adoption in some of the most robust, decentralized, and fast blockchain protocols.

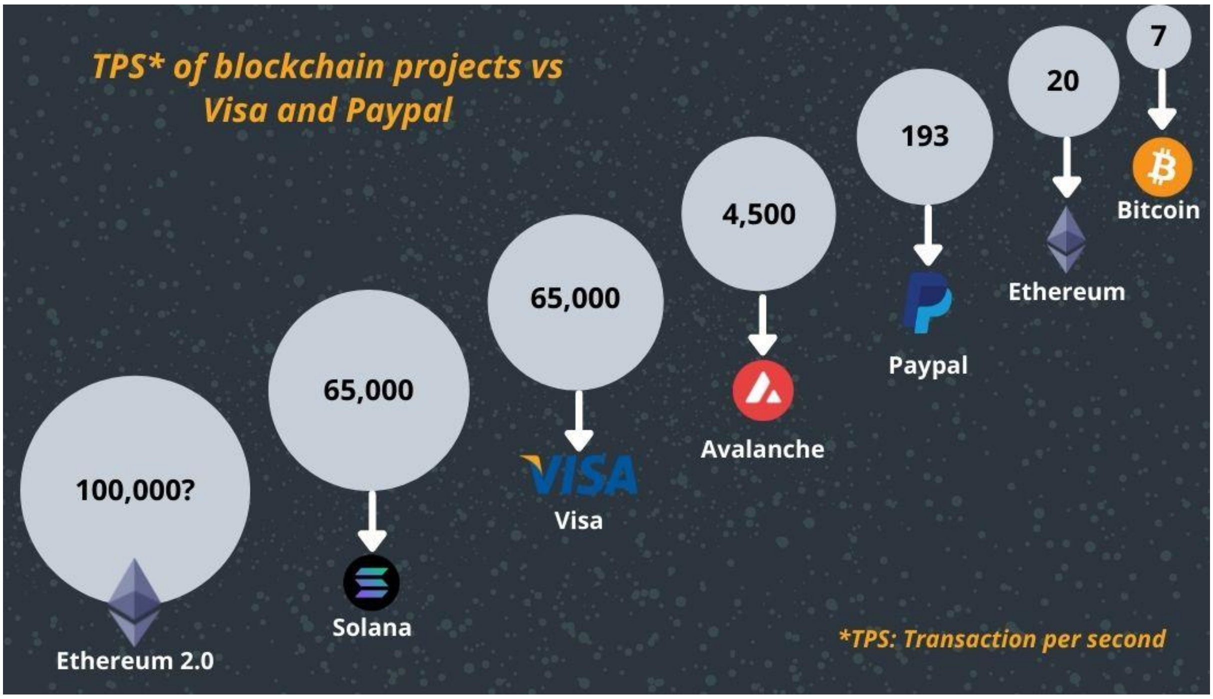


Figure 2: Data for VISA and Ethereum previously cited. Data for Solana is from: (Fonda, 2021) Copyright 2021. Data for PayPal and Bitcoin from: (Mechkaroska, Dimitrova, & Popovska-Mitrovikj, 2018). Data for Avalanche (AVAX) obtained from: Avalanche documentation -(https://support.avax.network/en/articles/4136568-how-many transactions-per-second-does-avalanche-support) Copyright 2021.

PoS offers several advantages compared to PoW. However, the threat of a 51% attack is not solved. Some projects create mechanisms to contain them (Ethereum-Foundation, 2022) mention that such an attack is hazardous. In Ethereum, the attacker must gain access to 51% of the staked ETH, representing much money. Such an attack could collapse the value of the cryptocurrency, therefore, the value of the stake. These characteristics make a stronger incentive to keep the network secure. Another method of contention used by several protocols is penalties to the staking pools that punish bad behavior, resulting in the loss of cryptocurrencies staked.

On September 21, 2021, Solana (The most scalable PoS blockchain project up to date) suffered a 17-hour outage. Due to an overload, the blockchain network spiked to 400,000 vs. 65,000 transactions per second (maximum supported by the blockchain). At that point, the system crashed. The problem came from a social-network protocol called Grape which created a backlog of transactions in the blockchain protocol (Fonda, 2021). The same day Arbitrum, a solution built on Ethereum, went offline for 45 minutes due to a bug. In both cases, funds were not compromised. It is relevant to mention that both innovative projects are months old. Oddly enough, the same day, a failed attempt to breach the Ethereum protocol affected a small number of nodes before the attack was discovered. The nature of a highly decentralized blockchain makes it more secure and less prone to attacks.

2.5 Blockchain categories

Proof of Stake (PoS) offers several advantages compared to Proof of Work (PoW). However, the threat of the essential use of blockchain is the consensus model to create the computational ledger, sometimes referred to as the transaction ledger, which anybody can audit. These characteristics make the protocol suitable for parties that do not trust each other (Michael Casey, Jonah Crane & Narula, 2018).
The first type of blockchain is called a public blockchain. (Nakamoto, 2009) created the first type of blockchain applied in Bitcoin, a permissionless blockchain that falls into the public category. In the case of Bitcoin, anyone can join the network, become a miner, send transactions, compete in the consensus method, become a node to verify transactions, and read the transaction ledger. The Bitcoin blockchain allows anyone to participate in the protocol actively. The security compared to other blockchains comes from its economic incentives and the cryptographic verification of the consensus method PoW or PoS. These blockchains are considered fully decentralized and open to any participant willing to bring resources to secure the network.
The second type is private. (Buterin, 2015b) describes it as a blockchain where a centralized organization decides who can join the network. Reading the ledger may be public or restricted. A type suitable for applications such as auditing or database management inside a company, so the public cannot read the information inside the ledger. Still, the government may have access for audit purposes.
The third type is consortium blockchains. This type of blockchain falls into the permissioned category. However, this type of blockchain differs from the private in the fact that the blockchain is governed by a group of organizations or entities, rather than one entity, as in the case of private blockchains (Kathleen E. Wegrzyn, Eugenia Wang, 2021). Read permission may be public or restricted to their participants, or limited to a certain number of calls via an API. These blockchains may be considered "partially decentralized."

The fourth type is Hybrid blockchains. We can think of this type of blockchain as a mix of the public and private blockchain controlled by one entity. For instance, in a hybrid blockchain, the transactions and records can be made in private but can still be verified if it is needed. In other words, the information is kept private inside the network but still verifiable.
There is no need to discuss which category is the best. In reality, it is sufficient to note the registration of blocks of data in distributed ledgers can be achieved in various ways associated with differing levels of anonymity and data visibility amongst the participants. Everything depends upon the objective set and the intended use of such platforms (Allena, 2019).

2.6 Smart contracts

Bitcoin is the first blockchain application that keeps the state of a single ledger of transactions. Years later, Ethereum, the second-biggest blockchain project by market cap, introduced conditions to execute steps in an algorithm known as "smart contracts."
(Michael Casey 2018) explains that "smart contracts digital facilitate and enforce the transfer of digital assets according to software-defined contract conditions." In other words, the smart contract has a defined set of rules agreed upon by two or more parties. Once these conditions meet, the smart contract will execute a specific action agreed upon beforehand.
The most important characteristic of this feature is the decentralized nature of the blockchain. No intermediary or entity will enforce the contract terms because the blockchain will do it automatically. That unique characteristic makes it cheaper, faster and reduces the friction between parties compared to traditional systems. These are some reasons why companies and institutions turn to blockchain to solve their business problems.
As an international student who intends to study abroad, one of the main perquisites to be accepted in a master's program is validating a university diploma by a government institution where the document was issued. The idea is simple, the master's program wants to ensure that the submitted documents are legitimate. In some countries like Mexico, this process must be done in the state where the document was issued. In Mexico City, the validation costs around 36 euros or 6.8 minimum salaries (Mexican Government, 2021). Approximately after 6 hours and four supplementary documents, the result is a stamp issued by a government employee provided at his discretion.

Nevertheless, one of the most prestigious universities in the country is taking a different approach. In 2019 for the first time in Mexico, The Tecnológico de Monterrey issued digital college diplomas based on the Ethereum blockchain to more than 4000 graduates from 24 campuses around the country. This number has increased since the first pilot of 350 digital diplomas in 2018, with plans to expand this initiative to certifications. Just recently, another Mexican university started to take the same approach, the Universidad Tecnológica Metropolitana (UTM). This project aims to create a shared infrastructure to issue, verify, and store academic credentials that can be accessed easily. An initiative led by a group of 9 leading universities around the world: Delft University of Technology (The Netherlands), Harvard University, the Hasso Plattner Institute (Germany), MIT, Tecnológico de Monterrey (Mexico), T.U. Munich, UC Berkeley (USA), UC Irvine (USA), and the University of Toronto. (OEI, 2019).

The university describes the following advantages of the digital blockchain diploma:
1. It cannot be falsified
2. It can be verified by any entity that requires it
3. It can be included in other documents as a link
4. The information of the diploma in the blockchain will never disappear
5. Copies of a physical diploma become obsolete
6. The diploma can be retrieved immediately

As an international student, this is a powerful mechanism of smart contracts through blockchain technology that allow you to validate your skills and abilities to educational institutions, employers, and governments anywhere in the world.

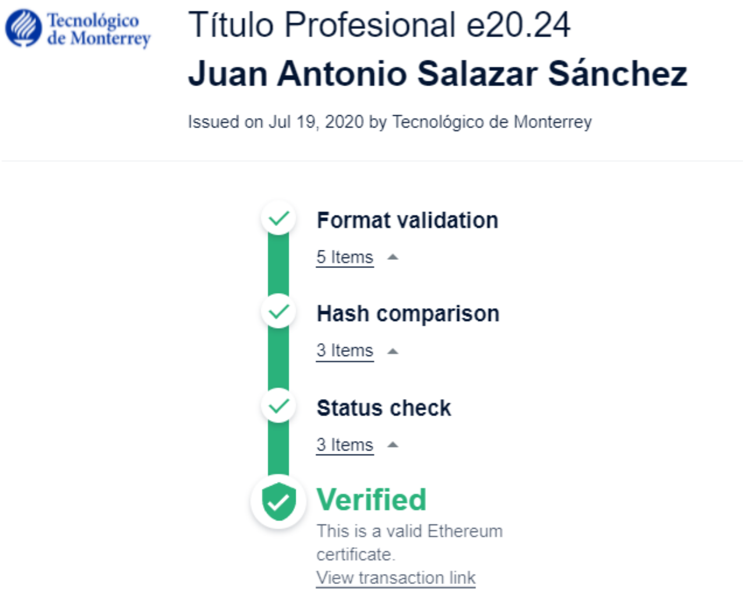


Figure 3: Verification of a digital blockchain diploma ethereum, (Salazar Juan Antonio, 2020).

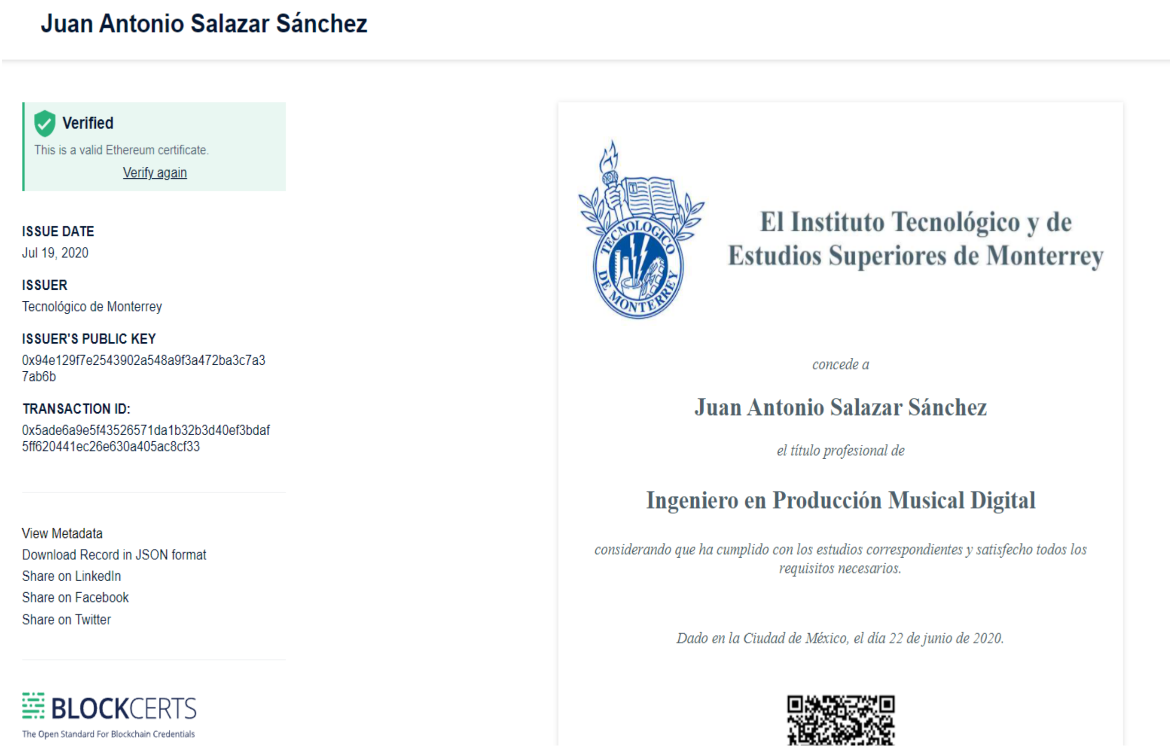


Figure 4: Verification of a digital blockchain diploma, (Salazar Juan Antonio, 2020). From:https://certificados.tec.mx/certificate/08dfa793bea65d2fb4a34ff13b32f557

2.7 Tokenization

The arrival of blockchain allows us different ways we can exchange assets. Tokenization is the process that plays this role in a blockchain system. It is the process of converting particular types of assets into a digital token that can be moved, stored, and recorded on a blockchain. In some ways, this may appear to be complicated. Tokenization is the process of converting an object's value, such as a painting or a carbon credit, into a token that can be exchanged and manipulated on a blockchain system.
For instance, Bitcoin can be said to represent the tokenization of computing power and electrical use into a medium of exchange. The aim here is to understand that a blockchain is a platform or system with a structure that permits the trading of items that can't be easily traded. For example, you can't trade computing power or electrical use without tokenization. Additionally, it has benefits over traditional paper markets in terms of speed, accountability, and security (EtoroX, 2020).
Tokens are classified in a variety of ways based on their varied properties. The main categories in terms of functionality fall into utility and security tokens. Utility tokens are used to access a service or act as a means of exchange inside a network.
BNB, for example, is a utility token that is primarily used to pay for trading costs on the Binance exchange. It can, however, be used to pay for products and services (Academy, 2022).
Security tokens, on the other hand, are tokens that represent monetary assets. During an ICO, a corporation could, for example, issue tokenized shares that offer the holder ownership rights and dividends, and these would be legal equivalents to traditionally distributed shares in a legal sense.

2.8 Sustainability definition

It has been possible to demonstrate how our society has degraded our planet for a long time. Today we are suffering the consequences of the actions and neglect of our planet that our past has left us, the climate change, shortage of natural resources, poverty, etc., are some examples of these consequences. These negative effects have alarmed our society, and now it seems that the world has woken up. Governments, people, and businesses are looking for ways to stop the degradation of our planet. Sustainability is one of these ways to mitigate the planet's degradation. In 1987, the United Nations Brundtland Commission defined sustainability as:

Meeting the needs of the present without compromising the ability of future generations to meet their own needs. (WCED 1987a: 43)

McGill University points out that we also need social and economic resources in addition to natural resources. Sustainability is not just environmentalism. Embedded in most definitions of sustainability, we also find concerns for social equity and economic development (McGill University, 2021). This definition emphasizes the importance of sustainability nowadays. To clarify, the following are some points that describe why sustainability is important.

- Ensures future for us and future generations

We all have a moral commitment to each other, future generations, and other species to keep the world alive, regardless of who we are, where we live, or what we do. Our current decisions and behaviors have far-reaching long-term consequences for future generations. Sustainability guarantees that we make ethical decisions that ensure everyone has a secure and livable future. Future generations will suffer if we exhaust the Earth's resources. If we overfish our oceans, for example, we risk diminishing the supply of fish and the supply of every item in the food chain that depends on that fish.

- Efficient energy consumption

Long-term energy costs are significantly reduced as a result of sustainable company operations. Some effective actions, such as switching to energy-efficient lighting on a production schedule, can save money in the long run. Monthly utility bills are reduced by utilizing solar and wind energy and energy-efficient equipment. Reducing energy usage is beneficial to businesses since it allows them to become more efficient in general.

- Improvement of living conditions

Our society can benefit from sustainability by improved water and air quality, increased renewable energy sources, and other sustainable actions. Sustainable actions help to make a significant change in society. Being environmentally conscious will reduce your carbon footprint and the number of contaminants discharged into the environment, making it safer. When we concentrate on sustainability, the entire planet benefits, and lives in cleaner, healthier environments.

2.8.1 Sustainability categories

There are three core pillars of sustainability: economic, social, and environmental. Cultural sustainability is a fourth pillar that is frequently mentioned. However, culture is fundamental for sustainable development since it incorporates the three core aspects mentioned earlier.

- Economic pillar

The economic pillar refers to the ability to create a sustainable economic system. In other words, they must embrace and promote environmental protection limiting the risks created by their production. As a result, recycled products and renewable energy, and raw materials are critical actions of the economic pillar.

It is also about providing incentives for businesses and organizations that incorporate sustainability practices into their organizational culture. Another aspect to consider is that incorporating sustainability practices in the company creates a good brand image in society, leading to more sales. Nowadays, some entities provide sustainability certifications, also called green certifications. For instance, the ISO 50001 standard, which focuses on energy management, attempts to improve energy performance with the goal of reducing consumption and, as a result, expenses. The successful implementation of this standard results in certification, which guarantees efficient energy consumption.

- Social pillar

The social pillar refers to upholding values that promote fairness and respect for individual rights. The social effects of a business operation are then evaluated in terms of these concerns. The following are the principles that this pillar is built on:

Mitigate social exclusion and discrimination: seeking reintegration, promoting gender equality, closing the gender wage gap, encouraging discourse, and enforcing global social rights, among other things.

Solidarity: cooperate with local and international organizations, associations, and projects to reduce social inequalities, prioritizing

Well-being for all stakeholders: fostering social conversation, encouraging information sharing and transparency, tailoring working hours to the needs of employees, and making facilities accessible to individuals with disabilities

- Environmental pillar

The environmental pillar refers to a commitment to protect the environment by reducing risks of degradation of our planet, particularly from businesses and governments. Some of the challenges for them are the following:

- Save and preserve natural resources
- Assess their carbon footprint and reduce their GHG (greenhouse gas) emissions
- Reduce and improve the management of waste

It also concerns how technology will drive our greener future; the EPA (Environmental Protection Agency) recognizes that developing technology and biotechnology is critical to this sustainability and protecting the environment of the future from possible damage brought on by technological breakthroughs. Thus, businesses must then set targets to improve their performance on environmental issues, referring to the challenges stated previously. These goals are an integral part of corporate social and environmental responsibility (CSR). We will further explore the concept of environmental sustainability in more detail later.

2.8.2 Sustainable development goals (SDGs)

In order to fight back against these sustainability challenges, governments, businesses, and society, in general, must be in the same channel. The United Nations (UN) is the organization that aims to create sustainability guidelines for everyone, are the world's largest, most well-known, most widely represented, and most powerful intergovernmental organization and the place where the world's nations can gather together, discuss common problems and find shared solutions.

In September 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development (Transforming Our World: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs, n.d.), in which they designed the 17 Sustainable Development Goals (SDGs). The 2030 Agenda refers that the sustainable development goals are integrated and act in the three core pillars of sustainable development – economic, social, and environmental -. The UN affirms that it is a plan of action for people, planet, and prosperity that also seeks to strengthen universal peace in larger freedom, to be implemented by all countries and stakeholders, acting in collaborative partnership, and reaffirming further all the principles recognized in the Agenda and that eradicating poverty in all its forms and dimensions, including extreme poverty. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests (THE 17 GOALS | Sustainable Development, n.d.).

The sustainable development goals designed in the 2030 Agenda are shown in Figure 5.

Figure 5: Sustainable Development Goals (United Nations, 2015)

Each sustainable development goal has several targets and indicators. The General Assembly from the UN decided in the 2030 Agenda that the SDGs with their respective targets and indicators will be followed up and reviewed by the Inter-Agency and Expert Group. In the same resolution it is stated that the follow up and review of the 2030 Agenda will be performed annually involving all high political actors in cooperation with the United Nations system, based on the global indicator framework.

With less than ten years to achieve the Sustainable Development Goals, world leaders agreed in September 2019 at the SDG Summit to call for a Decade of Action and Delivery for Sustainable Development, pledging to mobilize financing, improve national implementation, and strengthen institutions in order to achieve the goals by 2030, leaving no one behind.

2.9 Environmental sustainability

When we hear about environmental sustainability, many people link it with the conservation and protection of the ecosystem. In reality, environmental sustainability

covers more than that. According to the United Nations (UN) World Commission on Environment and Development, environmental sustainability is about acting in a way that ensures future generations have the natural resources available to live an equal, if not better, way of life as current generations (UN,2020). While the UN's definition is not widely agreed upon, it is fairly conventional. It has been modified over time to incorporate viewpoints on human needs and well-being, including non-economic variables such as education and health, clean air and water, and the preservation of natural beauty. A more detailed definition is the following:
Environmental sustainability could be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity (Morelli, n.d.).

The variety of definitions of environmental sustainability generally raises more questions about how we can contribute and be part of environmental sustainability as a single actor. There are different ways to contribute to environmental sustainability, including:

- Restructure the living conditions by incorporating and increasing eco-villages and sustainable cities
- Reassessing economic sectors (permaculture, green building, and sustainable agriculture) or work practices (sustainable architecture, for example).
- Developing new technology that helps the purpose of environmental sustainability, making adjustments in individual lifestyles that conserve natural resources (such as green technologies, renewable energy)

Another aspect to consider is how governments approach fostering environmental sustainability, such as regulations. Due to economic, social, and ecological conditions differ from country to country, there is no uniform blueprint for implementing sustainability measures. To ensure that sustainable development is pursued as a global goal, each country must adopt its own concrete strategy.
For instance, in the United States (U.S), the Environmental Protection Agency (EPA) is responsible for setting and enforcing regulations that involve environmental sustainability and protection. These regulations cover:

- Air quality
- Water quality
- Soil quality
- Plant life
- Animals and wildlife habitats
- Hazardous waste
- Greenhouse gas emissions

Environmental law violations are classified as white-collar crimes, and violators may face fines, jail time, probation, or a combination of the three. However, most businesses only pay fines when they break the law. As the EPA for the U.S, most countries have an entity responsible for setting the regulations for environmental sustainability. However, despite the great effort of the UN to promote, communicate and facilitate the implementation of environmental sustainability in the nations, there is a big disparity in the advances between developed countries and not developed countries. Unfortunately, environmental sustainability practices and regulations are way below on the sustainability journey for not developed countries.

2.9.1 Environmental sustainability challenges

In September 2019, the UN Secretary-General called on all sectors of society to mobilize for a decade of action on three levels: global action to secure greater leadership, more resources, and smarter solutions for the Sustainable Development Goals (SDGs); local action embedding the needed transitions in the policies, budgets, institutions and regulatory frameworks of governments, cities and local authorities; and people action (UN, 2019). There is no doubt that environmental challenges are a top priority for all governments and researchers worldwide. To meet the rising demand for raw materials, we use intensive and polluting practices that harm ecosystems. The actions that society and governments make now will determine humanity's destiny, and these decisions are also influenced by the daily choices of every single actor.
To tackle environmental challenges, all governments and society have to contribute to be successful. Most critical environmental issues are discussed in the section below.

o Pollution

Environmental pollution is a global problem that affects every part of the globe. Pollution impacts all types of life forms in some way, and pollution impacts organisms living at the poles or deep under the sea, where people do not even habit.
Each year a wide range of pollutants are spread into the environment through industrial emissions. The data reveals that more than 1,40,000 new chemicals and pesticides have been synthesized since 1950 (Landrigan et al., 2017). Just a few of them have been assessed for toxicity, such as polychlorinated biphenyls (PCBs), polyethylene, hydrochlorofluorocarbons (HCFCs), and chlorofluorocarbons (CFCs). Another factor is the high consumption of fossil fuels to meet the world's energy demands, and it is one of the major causes of air pollution and global warming.
Plastics are another example of pollutants that damage the earth. Because of their harmful effects on ecosystems worldwide, plastics are an ecological and environmental disaster. Approximately 79,000 tonnes of plastic are thrown into the Pacific Ocean each year. Despite the devastating repercussions of plastics, the manufacturing of these toxic

compounds continues to rise by the minute, and the world has become a landfill for these non-biodegradable substances.

Toxicants such as heavy metals have been damaging land and water due to rapid urbanization, industrialization, and other anthropogenic activities (Yadav, 2010). Although heavy metals are naturally present, human activities raise their concentration to dangerous levels (Arora et al., 2018).

- Climate change and global warming

There are many factors that impact or control the climate change of the earth including solar energy production, volcanic eruptions, GHG concentrations in the atmosphere, and aerosols. There is no doubt that the global climate is constantly changing, especially since the Industrial Revolution. Climate change is now occurring at a very fast rate due to an increase in anthropogenic activities such as industrialization, urbanization, deforestation, modern agriculture practices, change in land use pattern, and many others (Mahato, 2014). Climate change is currently occurring mostly as a result of increased emission and accumulation of GHGs such as (CO2), methane (CH4), nitrous oxide (N2O), water vapors (H2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6) (IPCC, 2013). It is now projected that changes in temperature over many parts of the globe are now expected to occur sooner than was expected (Li et al. 2018).

- Land degradation and agricultural constraints

Land degradation is another critical environmental issue not only to the compromised quality of soil but also linked to the diminution of the entire ecosystem along including biodiversity, biological cycles, ecosystem provisions such as carbon sequestration, forced migrations, even affecting food prices (Lal 2004; ELD-Initiative, 2013).

Climate change is a significant factor in land degradation and a reduction in the productivity and fertility of agricultural fields (FAO, 2017). Climate change has posed a threat to various terrestrial ecosystems, reducing vegetation density, negatively affecting soil microbial biomass, an essential component of agro-ecosystems, resulting in land desertification due to high temperatures, scarce rainfall, and resulting soil and water erosion (Cerdà et al., 2007). According to the report of FAO (2016), due to the warmer climate, significant crops (particularly the Rabi crops such as wheat) have experienced significant yield reductions globally.

Another threat that is sweeping more and more parts worldwide is drought. Droughts and floods have become more frequent as a result of climate change, and extended periods of water scarcity have resulted in desertification. Droughts have been more common over the world in the last 40 years, especially in the tropics and subtropics.

Soil salinization is another major cause of soil degradation that affects most countries, with a total area of about 1 billion hectares (FAO, 2022). Drought and salinization of fields are linked (Tewari & Mishra, 2018). The use of poor irrigation systems and agricultural practices have been the primary causes of soil salinization.

- Habitat and biodiversity loss

Biological diversity loss has become a complex and ongoing issue. This has resulted in a loss in biological variability, resulting in an extraordinary decline in terrestrial and marine species, including flora and wildlife, threatening ecological stability (Constanza et al. 1998). Plant extinction is a big problem since they play a critical part in maintaining ecosystem balance and have a direct impact on its functioning by providing habitat for a variety of other animals (Monteiro et al., 2018).
The most serious risks to biodiversity are habitat loss and fragmentation, which are mutually reliant (Hanski, 2015). Due to the population explosion, increased demand for resources such as land for agricultural purposes, expansion of cattle ranching, mining activities, and infrastructure construction has resulted in the metamorphosis of natural habitats, resulting in their degradation, and posing serious threats to plant and animal habitats (De Sherbinin et al. 2007).

2.10 Blockchain & Environmental Sustainability

Blockchain has been evolving and proliferating in recent years, and it is very likely to be the most popular and innovative technology worldwide nowadays. Blockchain is not just about cryptocurrencies; because of its unique characteristics, its application goes far beyond the cryptocurrency system, from governments and businesses to NGOs in different sectors such as supply chain, healthcare, banking and finance, agriculture, real estate, energy, and many other sectors. Even for sustainability purposes, governments have used this latter technology to enhance environmental sustainability.
In the case of environmental sustainability, blockchain technology can indeed help with new green manufacturing methods, the monitoring and storage of data-related activities that cause pollution and environmental damage, and the real-time collection and analysis of green or low-carbon data for prompt decision-making, and many other applications that still been to discover. The creation of a green supply chain can also be aided by blockchain. However, there is a debate among researchers about whether blockchain is good for the environment or not. While some researchers have emphasized the positive effect of blockchain, less attention has been given to the environmental challenges derived from this technology adoption. For instance, traditional blockchain systems require the use of a large amount of energy, creating consequently adverse effects on the natural environment; moreover, the host of big servers requires bulky buildings that can have a negative impact on the landscape (Parmentola et al., 2021).

Although it is accurate traditional blockchain system consumes a large amount of energy, this is changing rapidly. Most traditional blockchain systems work with Proof of Work (PoW) which is the consensus method that requires a large amount of energy. However,

new blockchain systems are moving to proof of stake (PoS) consensus method meaning a significant decrease in energy consumption. It is essential to mention that PoW and PoS are not the only consensus methods in the blockchain ecosystem; however, they are the most popular and used. Thus, for this paper, we will consider only them.
A clear example is the Ethereum network, the second most popular blockchain system is working on moving to the PoS consensus method (Ethereum 2.0). Another good example is one of the biggest rivals of the Ethereum network – Avalanche -. Avalanche (AVAX) blockchain launched in 2020 works with the PoS consensus method, and it has been categorized as an "Ecofriendly" blockchain network. These examples serve to demonstrate the evolution of blockchain and how it is adapting and countering the issues in our society, including the environmental ones.
At this pace and following the trend, it is only a matter of time that the impact of the consumption of energy from all blockchain networks, especially the traditional working with PoW, will be little significant. Taking this into assumption and considering the evidence so far, we can say that blockchain is taking the right path towards environmental sustainability.
To explore the different dimensions of environmental sustainability and how blockchain plays a role in it, we use the framework of sustainable development goals (SDGs) developed by the United Nations in 2015 (Table 1).

Table 1: SDGs and blockchain role

#SDGs	Description	Goal	Potentials	Challenges
	Clean Water and Sanitation	Ensure access to water and sanitation for all	Support peer-to-peer trading of water rights	Develop a new form of shared value creation in which a network of actors agrees on a specific objective to ensure equal use of the resource 'water'
	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all	Develop smart contracts for renewable energy producers and consumers	Develop blockchain systems based on alternative energy or reduced energy consumption
	Industry Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Develop smart contract for transport and logistics	Resources required can represent a barrier to the effectively implementation Define a set of incentives to sustain blockchain adoption
	Sustainable Cities and Communities	Make cities inclusive, safe, resilient and sustainable	Creating more liveable cities implementing platforms to monitor energy consumption, waste and so on	Define a blockchain model that integrate different technologies
	Responsible Consumption and Production	Ensure sustainable consumption and production patterns	Enables tracking and tracing of supply chains and natural resource usage	Require for a complementary assets to be effective
	Climate Action	Take urgent action to combat climate change and its impacts	Develop platforms for monitoring and exchange greenhouse gas emissions quotes	Develop blockchain systems based on alternative energy
	Life Below Water	Conserve and sustainably use the oceans, seas and marine Resources	Implementation mechanisms to monitor water pollution and preserve marine	Develop models for reducing waste and assessing the environmental impact thanks to complete
	Forests, Desertification and Biodiversity	Sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss	Offer small cash payments in exchange for conserving nature	Optimize energy processes, enabling communication between smart devices and making transactions with partners and suppliers more efficient

Source: Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs) (Parmentola, Petrillo, Tutore and De Felice, 2021)

Currently, many blockchain projects have emerged with environmental sustainability as a core of their business model. These projects differ in different fields, from energy trading and supply chain to charity or recycling and many other sectors. The essential highlight here is that these new businesses use blockchain technology as their primary technology and innovate with new ways to improve environmental sustainability.
Related work on blockchain and sustainability

2.11 Summary

The information in the literature review chapter serves as a basis for the research. It begins by describing blockchain's history and the fundamental ideas of blockchain technology. This section also comprises the delimitation of technological and social drawbacks of this technology.
The second section exanimated the concept of sustainability and the important role that it plays nowadays in our society. This section also analyzes the environmental sustainability concept, the challenges it faces, and mechanisms that have been developed, such as the SDGs, to tackle these challenges.
The last section of the literature review provides an overview of the role of blockchain in environmental sustainability, the disadvantages of implementing this technology for environmental sustainability, and how this technology is facing these disadvantages to become a potential solution for environmental issues.
To summarize, blockchain is an innovative technology with unique characteristics that seek to improve our society. Among these characteristics are visibility, traceability, trust, and flexibility. These characteristics of the blockchain have attracted the attention of many business sectors, governments, and NGOs, among others, and as a result, there has been rapid adoption of this technology, including environmental sustainability. Although numerous studies suggest that blockchain has a favorable impact on environmental sustainability, they also emphasize the need for a more in-depth examination of the disadvantages and challenges that it brings with it. Thus, this thesis aims to reach this objective by analyzing promising environmentally sustainable blockchain projects.

3 Methodology

To support the knowledge acquired in the literature study research. A qualitative analysis and an exploratory case study are used in this thesis. The approach of the methodology will be as follows. Firstly, the definitions and characteristics of an exploratory case study and qualitative content analysis in general are discussed.
Secondly, it is explained and defended why this strategy was chosen in particular and the details of the approach taken for the analysis. Finally, the basic principles of qualitative content analysis are discussed.
As previously claimed, a multi-method approach is used in this thesis. According to Kohlbacher (2006), the strength of this is that each approach has benefits and downsides, and the strengths of another will offset the weaknesses of one method. As a result, it is hoped the findings will be more reliable.
Qualitative research is used to acquire a better and deeper understanding of the issue. It consists of data gathered from many sources, data analysis, conducted evaluative analysis, and presentation of the results. (Yin, 2004) The qualitative research approach was employed for this thesis because it specifically strives to elucidate the blockchain phenomenon and acquire a deeper grasp of its role.

3.1 Exploratory case study

A case study is a sort of qualitative research that is used to investigate a phenomenon in a specific context. Case studies can be either single or multiple-case designs, with the latter requiring replication rather than sampling logic. The researcher is limited to single-case designs when no other instances are available for replication. Yin (1994) pointed out that generalization of results, from either single or multiple designs, is made to theory and not to populations. Multiple cases strengthen the results by replicating the pattern-matching, thus increasing confidence in the robustness of the theory. These claims reaffirm the multiple-case approach taken to robust the outcomes of the research.
A case study, according to Creswell (2013), "investigates a real-life, contemporary bounded system (a case) or numerous bounded systems (cases) across time through extensive, in-depth data collecting involving multiple sources of information and produces a case description and case themes" (p. 97). The unit of analysis, the study process, and the outcome all define a case study. Because of the complexity of blockchain technology, it is typically employed when the research topic is too large to be covered by questionnaires or experiments (Merriam, 2009).

In the literature, there are various examples of case studies methodologies. Several instances were given by Yin (1993), along with the proper research design in each situation. There were recommendations for exploratory, explanatory, and descriptive case studies, as well as a general strategy to designing case studies. Each of those three techniques can be single or multiple case studies, with multiple case studies being replicatory rather than sampling as mentioned previously.
In this thesis an exploratory case study is carried out. In exploratory case studies, fieldwork, and data collection may be undertaken prior to definition of the research question and hypothesis. As described by Yin (2014), it aims to answer questions starting with ’how’ and ’what.’ Selecting cases is a difficult process, but the literature provides guidance in this area (Yin, 1989a). Stake (1995) suggested that the choice provides an opportunity to knowing that time is limited, optimize what can be learned. As a result, the cases chosen should be simple and willing topics.
Three factors set by Yin (2009, p. 2) were met in order to ensure that this research meets with formal norms of a well-conducted case study:

- “how” questions - This thesis points at answering how exactly blockchain addresses environmental sustainability in the selected cases.
- Investigator cannot manipulate variables over events
- A contemporary phenomenon - Blockchain and its real-world application and usability are intensively discussed topics and a contemporary phenomenon

The data collection could be almost from anywhere, these are some good examples of types or sources to collect the data: articles, annual reports, conference recording, testimonies, white papers, case studies, audio/ video interviews, speeches, books, magazines, websites and more recently social media such as Twitter, LinkedIn and Facebook. For this paper the main type of data sources were scientific articles, websites and “white papers”. For instance, a Google search for “blockchain for environmental sustainability” could lead us to a number of web media articles addressing blockchain projects working on environmental sustainability. The intention of this thesis is not to map all existing “Blockchain for environmental sustainability” projects, nor to provide a representative random sample, but to construct a diverse sample of projects allowing for an exploratory study. We excluded projects that were only suggested in an abstract form, and not in active development by any organization or group of developer.
The ideal number of projects explored in this paper was taken into account. According to Rowley (2002), case study research typically involves 6-10 projects. As the number of participants grows, the study's findings become more solid and relevant, and more major conclusions may be formed. Furthermore, it is desired that the scope of a project is comparable in terms of the information supplied.

The projects are analyzed using descriptions derived from their websites, technical 'white papers', or other comparable sources. White papers provide a solid foundation on which to analyze the nature of blockchain initiatives because the blockchain community is often fairly detailed in its presentation of white papers, containing extensive technical depth. They may try to portray projects in the best possible light. However, if there are concerns with sustainability in the white papers, they are likely to exist in the implementations as well.
Lastly, all data for the research presented in this paper was obtained in the second half of 2021 and the first half of 2022.

3.2 Content analysis

Content analysis is a method for analyzing the content of a variety of data, such as visual and verbal data. It enables the reduction of phenomena or events into defined categories so as to better analyze and interpret them (Harwood & Garry, 2003). According to TITSCHER et al. (2000, p.62), a debate concerning content analysis research methodologies erupted in the 1950s. The first book on content analysis in communication research was written by BERELSON (first published in 1952) a compilation of quantitative content analysis methods and goals that had been created up to that point, with a focus on evaluation on the basis of frequency studies (BERELSON, 1971). The article by KRACAUER from 1952 "'The qualitative content analysis is a challenge "may be interpreted as a critical response to the book by BERELSON (KRACAUER, 1952). He claimed that the quantitative data was flawed. The importance of text quality was overlooked in the orientation process. reassemble contexts Counting and measuring, he claims, isn't the way to go. BRYMAN (2004) states that qualitative content analysis is "probably the most prevalent approach to the qualitative analysis of documents" and that it "comprises a searching-out of underlying themes in the materials being analyzed" (p.392). Being a little bit more specific he defines qualitative content analysis in the following way:

> "An approach to documents that emphasizes the role of the investigator in the construction of the meaning of and in texts. There is an emphasis on allowing categories to emerge out of data and on recognizing the significance for understanding the meaning of the context in which an item being analyzed (and the categories derived from it) appeared" (BRYMAN, 2004, p.542).

For this paper, the content analysis will be performed as follows. Firstly, the difficulties addressed to assess the potential influence of blockchain on environmental sustainability management derived from the literature review. They serve as the foundation for the effect evaluation outlined in the review and a core coding sheet for content analysis. Secondly, as part of the collected content, a coding procedure will be searched for the difficulties and a summary at the end of each case investigated.

To conclude, this thesis employs two qualitative research techniques. In order to acquire secondary data, an exploratory case study is used first. Second, a simplified content analysis based on the case studies was undertaken using the coding procedure to make conclusions.

4 Analysis

Relevant blockchain projects are compiled and analyzed briefly in this chapter. Six projects are selected at the end of the chapter and later serve as the basis for the primary study undertaken at the end of this chapter.

4.1 Case selection

The first step for data collection was to find blockchain projects related to environmental sustainability. The requirements for the search were as follows: A project must implement a blockchain-based platform, the project's information must be publicly accessible over the internet, and it must be either academic, non-commercial, or commercial. Most of the projects were found organically on websites and through online articles addressing blockchain projects working on environmental sustainability. For instance, a good example of an online article with relevant projects is "Top 5 blockchain projects for ecology" (Novikova, 2019). These projects were re-evaluated and revised as needed. The strategy taken to find projects through websites was to use keywords on the search engine (Google), keywords such as "blockchain projects", "blockchain and sustainability", "cryptocurrencies into sustainability", "environmental blockchain projects". Since blockchain for environmental sustainability is a quite narrow topic, through these key words was possible to identify projects for our research although very little variety of projects. Fortunately, nowadays, many websites related to blockchain or cryptocurrencies frequently talk about new blockchain projects coming up. A good example is "coindesk.com." This search was not structured in any specific way, and it was primarily motivated by practical considerations. In total, six projects were selected to further research, and they are presented at the end of this chapter.

4.2 Categorization

In the following section, each project is categorized with a specific criteria to follow them up in a more structured way. For this categorization we took the same framework categorization from the study conducted by Gonczol et al. (2020) "Blockchain Implementations and Use Cases for Supply Chains”. Three fields were additionally added in the categorization; year of foundation, category and subcategory. While three fields were deleted; product type, focus and industry/academic. In total, it includes the following data fields.

a. Name

b. Year of Foundation

c. Category – This field relates to point out the particular area the project focus on. For instance, while one project focus in the energy sector another one in public health.

d. Subcategory – This field refers to point out the mechanism or way which the project uses blockchain technology for the environmentally sustainable purpose

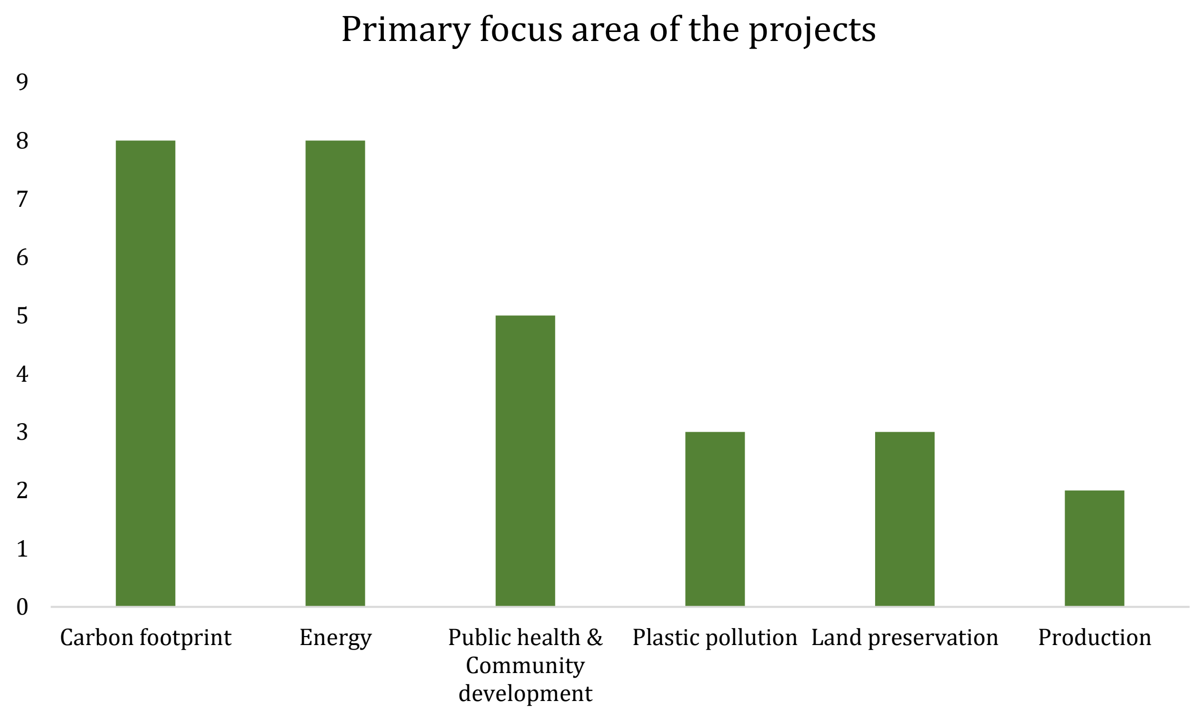
e. Platform – This category is relatively significant since it mentions the blockchain network that the project is utilizing for its operation. The Ethereum blockchain playing as the main actor among other networks, operates with a permissionless mode and proof of work as consensus method, this is important to be aware from the environmentally sustainable aspect since as we discussed previously in this paper it can impact negatively the environment due to the high consumption of energy. Although this is changing and it slowly undergoes the shift towards the Proof-of-Stake consensus method, it is not still the reality yet. Other blockchain networks mentioned are Solana, Avalanche, among others.

f. Status – This field refers to the stage of the project. Proof-of-Concept, Pilot, and Production stages are the three stages considered. This feature ensures that only projects that are currently in the production or pilot stages will be investigated further in Chapter 5. As a result, it is consistent with the goal of this study, which is to conduct an empirical investigation of the current situation. The fact that the Proof-of-Concept stage often establishes technical feasibility is one of the reasons why it is not appropriate. It does not, however, address issues such as acceptance, usability, or the solution's overall impact.

g. Access rights – This field refers to indicate whether or not a blockchain network participant must be identified and approved before joining the network. For instance, the Ethereum network is permissionless in general. In contrast there are blockchains that take a different approach such as permissioned or hybrid.

4.3 Interpretation

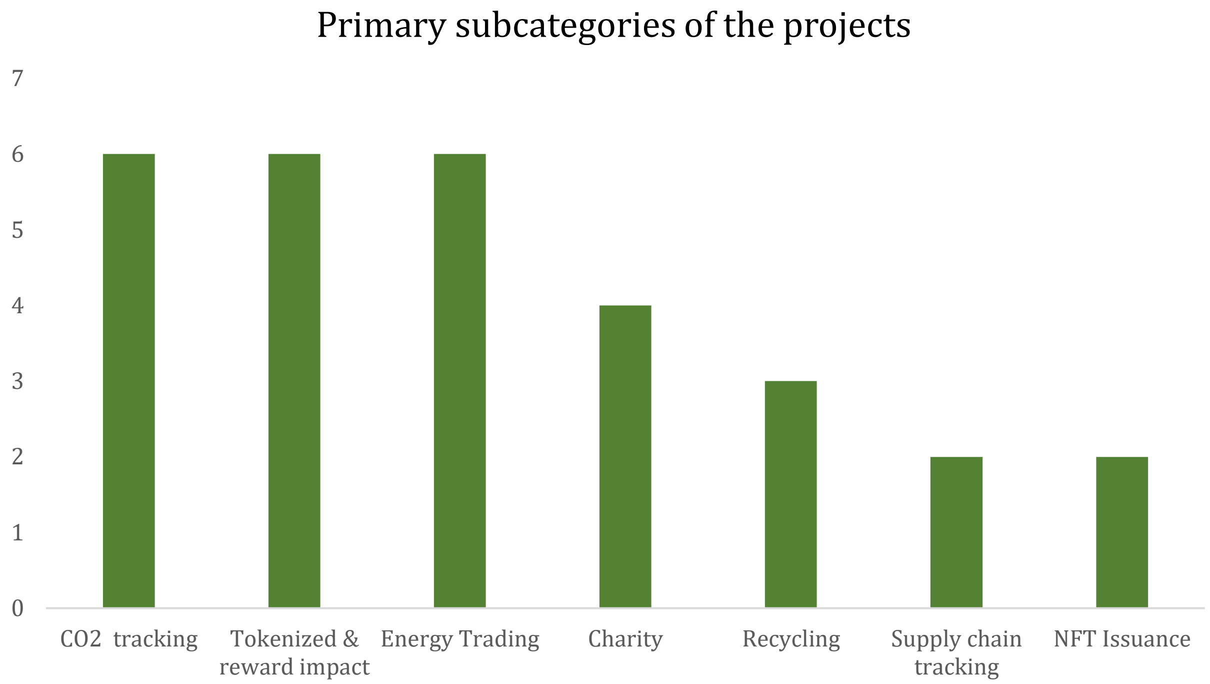
Table 2 shows the projects that were collected, and the figures below were created using this information. Figure 6 presents an illustrative representation of the project's major focus. It is evident that the majority of the cases are primarily focus on carbon footprint and energy. Public health and community development come next, followed by plastic pollution and land preservation, lastly, we have production.



Source: Author

Figure 6: Primary Focus area of the projects

When it comes to subcategories CO2 tracking, tokenized & reward impact and energy trading are the ones that lead. Followed by charity, recycling supply tracking and finally nft issuance. Figure 7 illustrates the subcategories within the projects.



Source: Author

Figure 7: Primary subcategories of the projects

Table 2: List of Projects

ID	Project	Year of Foundation	Category	Subcategory	Platform	State	Access Rights
1	Basin	Unknown	Land preservation	CO2 tracking	Unknown	Proof of concept	Unknown
2	Bext360	2016	Production	Supply chain tracking	Stellar	Production	Hybrid
3	Bitgive	2013	Public health & Community developmen	Charity	Unknown	Production	Permisionless
4	Bithope	2014	Public health & Community developmen	Charity	Unknown	Production	Permisionless
5	CitizenDAO	Unknown	Public health & Community developmen	Charity	Ethereum	Proof of concept	Permisionless
6	Climate trade	2017	Carbon footprint	CO2 tracking	Algorand	Production	Permissioned
7	Climatecoin	2017	Carbon footprint	Tokenized & reward impact	Algorand	Pilot	Permissioned
8	Earthfund	Unknown	Public health & Community developmen	Charity	Ethereum	Pilot	Permisionless
9	Electron	2015	Energy	Energy Trading	Unknown	Production	Unknown
10	Energitoken	2016	Energy	Tokenized & reward impact	Ethereum	Pilot	Permissioned
11	Energy web	2017	Energy	Energy Trading	Energy web chain	Production	Permisionless
12	Hopu	2014	Carbon footprint	CO2 tracking	Solana	Production	Permisionless
13	LO3 Energy	2012	Energy	Energy Trading	Energy web chain	Production	Permisionless
14	Moss	2020	Carbon footprint	CO2 tracking	Ethereum	Production	Permisionless
15	Nori	2017	Carbon footprint	CO2 tracking	Unknown	Production	Unknown
16	Nozama	2019	Plastic pollution	Recycling	Binance smart chain	Production	Permisionless
17	Oxyn	2018	Plastic pollution	Recycling	Unknown	Proof of concept	Unknown
18	Plastic bank	2013	Plastic pollution	Recycling	Hyperledger	Production	Permissioned
19	Poseidon	2017	Carbon footprint	Tokenized & reward impact	Stellar	Production	Hybrid
20	Powerledger	2016	Energy	Energy Trading	Ethereum	Production	Permisionless
21	Projectark	2021	Carbon footprint	NFT Issuance	Chainlink	Production	Permisionless
22	Provenance	2016	Production	Supply chain tracking	Ethereum	Production	Hybrid
23	Regen network	2017	Land preservation	Tokenized & reward impact	Regen network	Production	Permisionless
24	Rewilder	Unknown	Land preservation	NFT Issuance	Ethereum	Pilot	Permisionless
25	Seeds	Unknown	Public health & Community developmen	Tokenized & reward impact	Unknown	Production	Unknown
26	Solarcoin	2014	Energy	Tokenized & reward impact	Energy web chain	Production	Permisionless
27	Suncontract	2016	Energy	Energy Trading	Ethereum	Production	Permisionless
28	Toucan	Unknown	Carbon footprint	CO2 tracking	Polygon	Production	Permisionless
29	Wepower	2016	Energy	Energy Trading	Ethereum	Production	Permisionless

Table 3 shows the maturity of the cases, and most of them were in the production state, followed by Proofs-of-Concepts and at the end pilot state.

Table 3: Maturity of the projects

Status	Projects																												
Pilot							7	8		10														24					
Production		2	3	4		6			9		11	12	13	14	15	16		18	19	20	21	22	23		25	26	27	28	29
Proof of concept	1				5												17												

Source: Author

4.4 Exclusion and inclusion criteria

Only those projects that meet the particular criteria can be included for a deeper and more in-depth examination. These criteria are intended to exclude projects that are in an early stage of development, that lack of information such as year of foundation, blockchain platform, not clear access right, have limited and confusing information in their activities.

Criteria 1 (CR1): Projects that were not able to find the year of foundation or that their year of foundation is from 2021 were excluded. The year of foundation provides a reference of the maturity of the project thus it is important. After applying this criterion, 22 projects were left.
Criteria 2 (CR2): Projects that will not be further studied are projects with the state of pilot and proof of concept. This thesis aims to study projects that are already being implemented and are in the production state. After applying this criterion, 19 projects were left.
Criteria 3 (CR3): Another set of projects that will not further be studied are the projects that do not have a clear access right. After applying this criterion, 17 projects were left.
Criteria 4 (CR4): Projects that do not mention the blockchain network with which they operate will be excluded as well. The blockchain network is essential to know for our aim of the research. After applying this criterion, 15 projects were left.
Criteria 5 (CR5): Blockchain networks that work with proof of work as the consensus method are not the ideal approach for environmentally sustainable projects. For instance, LO3 energy project started operating with Ethereum network, in 2020 they announced the migration to energy web chain because it goes align with their environmental vision. Thus,

projects working with proof of work consensus method will be excluded. After applying this criterion, 10 projects were left.
Criteria 6 (CR6): Last criteria refers to how good is the project engaging with people, how active is through social media, newsletters, conferences, articles, magazines, networking, etc. Projects that are active through social media, engaging with the people, generating leads and brand awareness are most likely to survive in the market than the ones that don't do it. Thus, this criterion helps to determine the most promising projects to survive in the market. After applying this criterion, 6 projects were left.

4.5 Short List

The following projects are further examined after taking prior exclusion criteria into consideration.

ID	PROJECT NAME	CR1	CR2	CR3	CR4	CR5	CR6	STUDIED
1	Basin							
2	Bext360	●	●	●	●	●		
3	Bitgive	●	●	●				
4	Bithope	●	●	●				
5	CitizenDAO							
6	Climate trade	●	●	●	●	●	●	●
7	Climatecoin	●						
8	Earthfund							
9	Electron	●	●					
10	Energitoken	●						
11	Energy web	●	●	●	●	●	●	●
12	Hopu	●	●	●	●	●		
13	LO3 Energy	●	●	●	●	●	●	●
14	Moss	●	●	●	●			
15	Nori	●	●					
16	Nozama	●	●	●	●	●	●	●
17	Oxyn	●						
18	Plastic bank	●	●	●	●	●	●	●
19	Poseidon	●	●	●	●	●		
20	Powerledger	●	●	●	●			
21	Projectark							
22	Provenance	●	●	●	●			
23	Regen network	●	●	●	●	●	●	●
24	Rewilder							
25	Seeds							
26	Solarcoin	●	●	●	●	●		
27	Suncontract	●	●	●	●			
28	Toucan							
29	Wepower	●	●	●	●			

4.6 Examination of the cases

In this section, additional details about selected projects are offered, and an analysis is undertaken. The following details are presented for each project scenario.

1. Project's history - Who launched the project, what is the aim of the project?
2. This section describes how a particular solution works from a technical perspective and how blockchain is integrated.
3. Competition/ Similar Projects (if available) - Projects that seek to address the same problem
4. Impact of the project on environmental sustainability

Even when some initiatives have been in operation for a number of years and have been tested by numerous companies, it may be difficult to evaluate their influence on a specific challenge based on the available data. In such instances, impact descriptions are omitted. In addition, there is no precise structure for the examination of a project. Each project is described separately based on the facts provided.

4.6.1 Project Case 1: ClimateTrade

ClimateTrade is the only project that falls into the carbon footprint category. Founded in 2017 by Fran Benedito, it is an innovative project that aims to meet climate action goals by offsetting carbon dioxide emissions with innovative digital solutions. In this case, the main product of this project is a marketplace platform that is carbon-neutral projects, and users can cooperate in any of them. In other words, ClimateTrade puts companies that need to offset their carbon emissions in contact with many verified environmental projects (CT3).

In these five years of existence, ClimateTrade has been developing its digital solution and partnering with big companies. Until today it has over 500 companies registered, over 2,700 final users, over 3M tons of carbon offset, and over 60 projects from +20 different countries. Blockchain technology plays a key role and applying this technology to the world of environmental compensation achieves the definitive level of traceability in these operations. Because thanks to the multinodular information storage system, its transparency and speed are multiplied (CT1).

For ClimateTrade, blockchain technology brings innovation and transparency to the carbon market, but how is it integrated?

In the Kyoto agreement (1997), signatory nations agreed to restrict the emissions of six greenhouse gases; this is the genesis of carbon credits. This meant that instead of paying taxes to the government, polluting firms might pay directly to the corporations that generate the credits (CT4).

Like any standard market, brokers began to speculate and obtain the majority of profits, limiting funds from reaching green projects and impeding their growth. This left not just carbon credit vendors exposed but also buyers who may be offered the same credit many times (due to the lack of transparency and traceability of the carbon credits cancellation mechanism) (CT4).

As is customary, the problem was that the market was consolidated in the hands of traditional brokers, who used to administer their databases that may be altered at will, with the ability to add, delete, modify, and restrict access, among other operations. Additionally, the procedure grows more expensive, time-consuming, and cumbersome, preventing many businesses from purchasing or selling carbon credits (CT4).

ClimateTrade eliminates this issue, enabling businesses and project creators to profit from blockchain technology.

Blockchains are distributed ledgers that copy data throughout the network's participating nodes (CT5).

That is, rather than being centralized on a single server, the information is dispersed across multiple computers, each of which stores its copy. This prevents any record from being modified or deleted, as it only permits adding new data, avoiding data manipulation (CT5).

The information on a public blockchain is open to all and visible to any block explorer, which facilitates the traceability and transparency of cancelled carbon credits. Since all nodes are compelled to obey the consensus algorithm, which ensures the immutability of data stored in them, neither ClimateTrade nor the blockchain's creators could change the information (CT1).

Proof of Stake is the consensus algorithm utilized by the blockchains ClimateTrade works. The original blockchains (Bitcoin and Ethereum 1.0) use Proof of Work, which requires enormous energy to produce new blocks and concentrates the power in the hands of a small number of mining pools (CT1).

Proof of Stake, on the other hand, enables the processing of a greater number of transactions per second by decentralizing the rewards per block to anyone who operates the blockchain token with a connected laptop or mobile device, thereby saving on transaction fees and reducing environmental impact by more than 99 percent (CT1).

To advance the automation process, ClimateTrade has made a REST API available to companies wishing to incorporate this unique approach. This enables the incorporation of projects already in existence that call this API into its code, thereby offsetting the carbon footprint generated by their business activities (CT1).

ClimateTrade uses the Algorand blockchain network because its consensus is not based on energy-intensive proof-of-work and requires minimal computational power or electricity. Algorand has been a leader in minimizing the environmental impact of blockchain technology (CT2).

"Clean energy and addressing climate change are priorities for the United Nations, global organizations, and governments. Algorand has a very low carbon footprint, to begin with, and we are inspired by the leadership role the organization is taking to ensure the next generation of blockchain adoption is environmentally friendly," said Francisco Benedito, CEO of ClimateTrade.

Algorand with ClimateTrade will implement a sustainability oracle that verifies Algorand's carbon impact on-chain for each epoch to realize a carbon-negative network (a set number of blocks). Algorand will then use its sophisticated smart contracts to lock the corresponding amount of carbon credit as an ASA (Algorand Standard Asset) into a green treasury so that its protocol continues to operate carbon-negative.
Through this agreement, Algorand can leverage several of our marketplace's initiatives to compensate for their network's small footprint (CT2):

- The Southern Cardamom REDD+ project was initiated by Wildlife Rescue and Wildlife Works, which protects the rainforest by avoiding more than 3 million tons of carbon emissions annually.
- The Vichada Gold Standard Climate Project is aimed at reforestation in the Orinoco Department in Colombia.
- The Oaxaca Wind Project by Acciona covers the electricity demand of 700,000 Mexican homes, avoiding the emission of 670,000 tons of $CO2$.
- The Sumatra Merang Peatland Project by ForestCO2 aims to protect and restore the peatland ecosystem in Indonesia.

With this alliance, ClimateTrade not only works to achieve the carbon neutrality of Algorand but also to positively impact the environment, which is how every innovative blockchain ecosystem should be in the future (CT2).

In terms of competition, we found three main competitors in the market for ClimateTrade. Even though they are not operationally similar, the aim of these projects is similar to ClimateTrade.

- Climatecoin: A basis for creating a global market for carbon emissions, allowing peer-to-peer exchange of carbon credits and a direct connection to the Internet of Things.
- Poseidon: Poseidon can quickly analyze the carbon footprint of any product or service and then process carbon credits in fractions small enough to rebalance the product or service at the point of sale.
- Nori: Own, Track, and Showcase Verified Carbon Removal reverse climate change with the most transparent carbon removal marketplace.

Despite the competition and new projects coming up with a similar digital solution as ClimateTrade, ClimateTrade remains in a good position in the market. The team has been doing a great job partnering with companies, branding, etc, and it looks promising future for the project.

The impact of the project on environmental sustainability has been remarkable. Here are some of the biggest projects (CT1):

- Banco Sabadell: Banco Sabadell has teamed with ClimateTrade to offset the greenhouse gas emissions resulting from its operations in 2021 by investing in Spanish forestry projects.
  Banco Sabadell continues to make strides in its commitment to sustainability and the environment, focusing on decreasing its own emissions, offsetting, and assisting clients in their move to ecological neutrality with sustainable solutions and advice. The Bank has supplemented its action plan in 2021 with the compensation of its carbon footprint through carbon dioxide mitigation projects that have a positive impact in the regions where they are created.
- Suez environment: Within the framework of its commitment to sustainability, Suez has pledged to offset CO2 emissions through the Aquae Foundation by financing, on the ClimateTrade platform, the Nueva Aldea 1 biomass plant project in Chile, a 30-year-old biomass power plant that uses sawdust and bark as renewable fuel to generate heat and electricity.
- Lluch Essence: Lluch Essence launched a partnership with ClimateTrade in October 2019 in order to carry out the effective compensation of the carbon footprint of the first half of 2019, which comprised facilities, automobiles, commercial flights, and participation in trade shows. Conforming to the same premise, in March 2020, the corporation will compensate 619 tons of CO2 emissions from the second half of 2019, via ClimateTrade.
- Meliá Hotels: Under the slogan "Towards a sustainable future from a responsible present" and with the goal of promoting tourism under the threshold of sustainability and other values such as commitment, entertainment, innovation, and the environment, Meliá Hotels International has signed an agreement with ClimateTrade to offer its customers the option of offsetting their carbon footprint via the MeliáRewards program.

Table 4: Summary Analysis ClimaTrade

Category	Analysis
Blockchain application	Climate trade works with Algorands blockchain network, it has developed a marketplace which offers a variety of sustainabilty projects in which you can participate by compensating the tracking of C02 emissioned. Through blockchain Climate trade offers the transparency and trazability to participate in the projects offered. Smart contracts are the main blockchain application that Climate trade uses.
SDGs Commitment	
Enhanced Collaboration	Climate trade has partnered with several entities some of the major partners are: Algorand, Blockchain Association, Climate Chain Coalition, Climate Infrastructure Partnership, among others.
Customers	Some of the companies that Climate trade has in its customer portfolio are Iberia, Danone, Santander, Cabify, Mapfre, Melia Hotels, among others.
Revenue Stream	One of the revenue streams from Climate trade is the issue of a certificate once you join the marketplace. Customer pay to join the network and as a return Climate trade gives back a certificate.
Drawbacks	Despite Climate trade claims offer trazability and transparency due to blockchain, this can be debated. The implementation of a decentralized platform such as the marketplace developed by Climate Trade may not prevent private platform ownership from controlling the market and limiting democratic transparency. In addition, from a business perspective, achieving total transparency might not be attractive

Source: Author

Table 5: ClimateTrade – Overview of used sources

CT1	https://climatetrade.com/es/inicio/
CT2	https://www.algorand.com/ecosystem/use-cases/climatetrade
CT3	https://bit.ly/3PZHPrp
CT4	https://valenciaplaza.com/climatrade-el-amazon-de-las-empresas-para-compensar-su-huella-de-carbono
CT5	https://medium.com/iryo-network/public-vs-permissioned-private-blockchains-99c04eb722e5

4.6.2 Project Case 2: Energy Web

Energy Web (EW) is one of the projects that fall into the energy category, and it is one of the projects that have been best established in the market and has evolved impressively. Energy Web is accelerating a low-carbon, customer-centric electricity system by enabling any energy asset owned by any customer to participate in any energy market. Energy Web was founded in 2017 by Rocky Mountain Institute, Grid Singularity, and other affiliates (EW3).

During the first months of Energy Web (EW), their test net leveraged public Ethereum's Kovan network, but by November 2017, they had launched Tobalaba, an EW-built dedicated test net. It was a time of intense energy-sector interest in blockchain technology. Between Q2 2017 and Q1 2018, the industry invested some $322 million in energy blockchain start-ups. By early February, their community had grown to 37 Affiliates, and by summer 2018, they had named our founding CEO(EW2).

Then, the pace accelerated as the energy sector began exploring blockchain technology as a serious opportunity rather than a novel curiosity or possible disruptor. By March 2019, they had incredibly passed the 100-Affiliate milestone. Meanwhile, Affiliates and other partners have wasted no time adopting the Energy Web, launching proofs of concept, MVPs, and other solutions on Volta, our second-generation test net, including in cooperation with PJM-EIS, SP Group, Chile's CNE, Iberdrola, Acciona, Elia, Stedin, and others (EW2).

In June 2019, they launched the Energy Web Chain, the world's first public, open-source, enterprise-grade blockchain tailored to the energy sector. TEO by Engie became the first DApp to migrate onto the live production chain, while companies such as Thailand's PTT began building new commercial solutions (EW1).

Then in December 2019, they announced a significant update to the technology roadmap: the Energy Web Decentralized Operating System (EW-DOS). It is an open-source stack of decentralized software and standards—including the Energy Web Chain and various software development toolkits (SDKs). One month later, in January 2020, they announced a major first implementation of EW-DOS with Austrian Power Grid (EW1).

As electricity systems worldwide increasingly digitalize, they have become one of the leading partners helping energy market participants harness decentralized technology in support of a low-carbon, customer-centric energy future.

The Energy Web Foundation has conducted several funding rounds over two years, raising approximately $20 million and selling 21 million Energy Web Token and EWT coins (EW4).

Energy Web is a complex project requiring technical knowledge to understand how it was built and evolved during the time. To understand how blockchain technology is implemented in this project, let's examine its mission.

"Energy Web's mission is to accelerate decarbonization of the global economy. To do so, we deploy digital operating systems for energy grids with our global community of more than 100 energy market participants. These systems make it simple, secure, and efficient for clean energy assets to support the grid of the future" (Energy Web Foundation, 2019)

This mission accomplished will be possible through blockchain technology. As an integrator and, when required, a developer of decentralized technological solutions, the Energy Web Foundation (EWF) constructed and launched a global blockchain-based software infrastructure: the Energy Web Chain. In its current implementation, the EW Chain is a publicly accessible network with validators hosted by EWF Affiliate organizations. It uses a Proof-of-Authority consensus mechanism that has the potential for a 30x boost in performance and 2–3 orders of magnitude less energy consumption than Ethereum. In figure 8, we can see a representation of how the Proof-of-Authority consensus mechanism works.
EWF also operates two test networks to encourage energy blockchain research and innovation (EW1):

- Tobalaba, EWF's beta test network, is a sandbox environment for experimentation
- Volta, EWF's preproduction staging network, is used to test EW Chain client updates for production.

In addition, EWF is continuously developing software and hardware components to reduce the cost of application development and allow developers to concentrate on their 2 key differentiators. The EW Chain was introduced in June 2019 with a governance plan that enables further innovation. It is technically and administratively designed to be future-proof (EW2).

So, what is the approach so far for the Energy Web chain? First, the EW chain is an open source, publicly accessible blockchain derived from the Ethereum technology stack. It employs a Proof-of-Authority consensus technique to greatly enhance transaction volume and reduce energy consumption compared to Ethereum main net and other public blockchains. In addition to providing secure, low-cost, and efficient integration with hardware, the EW Chain provides innovative privacy preservation and permissioning capabilities that make it possible to limit data access for competitive and/or regulated energy market applications (e.g., smart meters). In addition, EWF has the technological development expertise and resources to continue developing the EW Chain infrastructure to meet the needs of the energy blockchain community, letting developers focus on rapidly deploying their applications in production environments at scale (EW2).

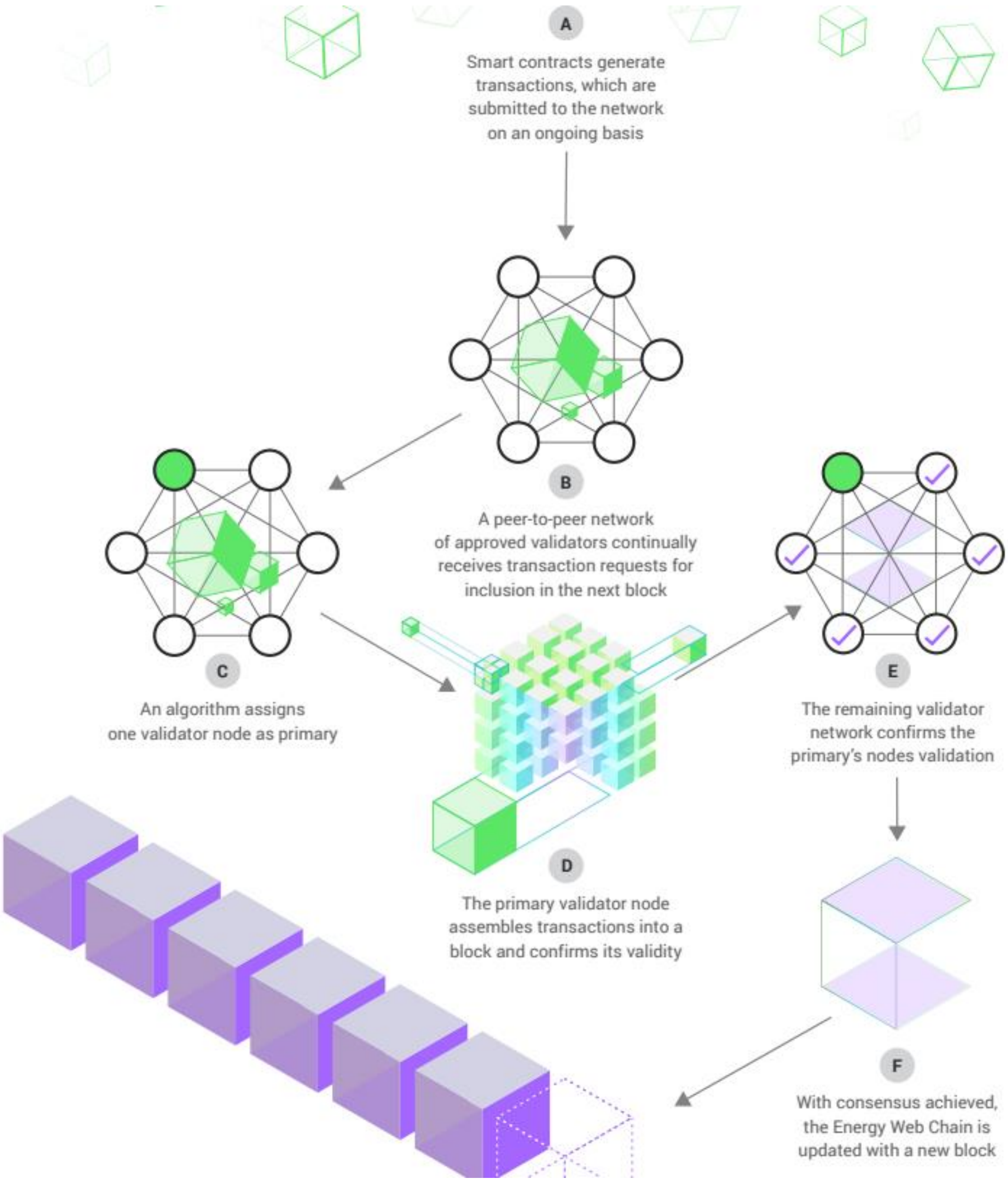


Figure 8: The Energy Web's Proof-of-Authority (PoA) Consensus Mechanism (Energy Web Foundation, 2019)

SDKs are publicly accessible hardware and software components developed on the EW Chain to speed application development. EWF has created three original versions to date:

1) EW origin: a reference application showing the transformative power of blockchain in renewable energy certificate and carbon accounting markets.
2) EW Link: a set of designs and protocols for securely connecting physical objects to the blockchain, allowing them to autonomously communicate and trade.
3) D3A: a vision and simulation tool for decentralized, democratized power markets enabled by the blockchain.

Energy Web project will continue cultivating an active ecosystem of affiliates, test and refine the existing features on their test net, build additional features, test and develop a functioning decentralized on-chain governance model, refine their three software SDKs, and launch additional SDKs and tools (EW1).

In terms of competition, we found two main competitors. Even though they are not operationally similar nor in the technology developed, the aim of these projects is quite similar to Energy Web.

- Electron: Electron is an Entech company accelerating the transition to Net Zero. Their technology enables operators of networks, systems, local energy markets, and distributed energy assets to unlock value in decarbonizing energy systems.
- Powerledger: Powerledger is the operating system for new energy markets enabling tracking and trading of energy, flexibility services, and environmental commodities. They have developed an energy and flexibility trading platform that allows households, organizations, and the grid itself to trade with each other.

The project's impact on environmental sustainability has been remarkable. They have grown the EW Community into the world's largest energy blockchain ecosystem, developing 46 projects, in 21 countries, for 41 partners. Here are some exciting projects (EW1):

❖ EDGE - Energy Demand and Generation Exchange: EDGE is a joint project with AEMO, Australia's national energy market operator, to better balance the electrical grid as it copes with a surge in deployment of Distributed Energy Resource (DERs) — such as rooftop solar and batteries

- ❖ EW Zero - an open-source tool for purchasing renewables and carbon removal: EW Zero is an open-source solution for purchasing renewable energy and carbon removal through a single, convenient digital interface to increase market access and transparency.
- ❖ E-Mobility Dashboard: An open platform for exchange of trusted data and services between electric vehicles, charging stations, and grid operators.

Table 6: Summary Analysis Energy web

Category	Analysis
Blockchain application	Energy web Foundation has developed its own energy marketplace where buyers and sellers can trade energy assets, this is possible through the smart contracts. In 2019, Energy web Foundation built its own open source blockchain specifically for the energy sector.
SDGs Commitment	
Enhanced Collaboration	In terms of collaborations, Energy web has done a good job partnering with big organizations. Some of its partners are Iberdrola, General electric, Shell, Siemens, among others.
Customers	Some of the companies that Energy web has in its customer portfolio are Vodafone, Ptt group, Filecoin, Engie, Protocal Labs, among others.
Revenue Stream	Energy Web Foundation charges its customers to use energy web chain, another revenue stream is the comission they charge on the energy marketplace they developed.
Drawbacks	Given the importance of the energy sector, distrust is unlikely to be beneficial. However, the energy sector is one of the most regulated sectors by governments. There are many countries where the state provides energy to its citizens, and not the private sector is allowed. In this context, these projects could be a threat and considered competition due to the decentralization they offer. This could lead to new laws for the energy sector, limiting the implementation of blockchain technology in the energy sector. Another aspect to consider is that implementing a decentralized platform such as the marketplace developed by Energy web may not prevent private platform ownership from controlling the market and limiting democratic transparency.

Source: Author

Table 7: Energy Web – Overview of used sources

EW1	https://www.energyweb.org/
EW2	https://www.energyweb.org/reports/the-energy-web-chain/
EW3	https://www.kraken.com/en-us/learn/what-is-energy-web-token-ewt
EW4	https://www.crunchbase.com/organization/energy-web-foundation

4.6.3 Project Case 3: LO3 Energy

LO3 Energy is the other project that falls into the energy category. There are two interesting facts about this project; the first is that it uses Energy Web chain as its blockchain network, and secondly, it is the oldest project on the list. It was founded in 2012 by Lawrence Orsini and William Collins. It is one of the best projects established in the market. LO3's mission is to accelerate the decarbonization of electric grids worldwide with a software platform that allows its partners to implement innovative compensation mechanisms that best support their customers and their networks (LE1, LE4).

LO3 Energy has developed two leading digital solutions for the energy market: Pando & Exergy.
Both digital solutions work with blockchain technology. Pando, LO3 Energy's flagship software platform, enables suppliers and clean energy developers to support 24/7 load matching and offer intelligent incentives to drive renewable energy adoption. It is a marketplace software where you can trade energy without a third party. Exergy is a distributed ledger system that functions across grid-connected hardware, a token system for transactive energy, and a foundation that advances market design and technology in tandem. Exergy generates, controls, and secures the data required to enable price as a proxy for control and optimal operation of electric power systems (LE2).

Exergy solution

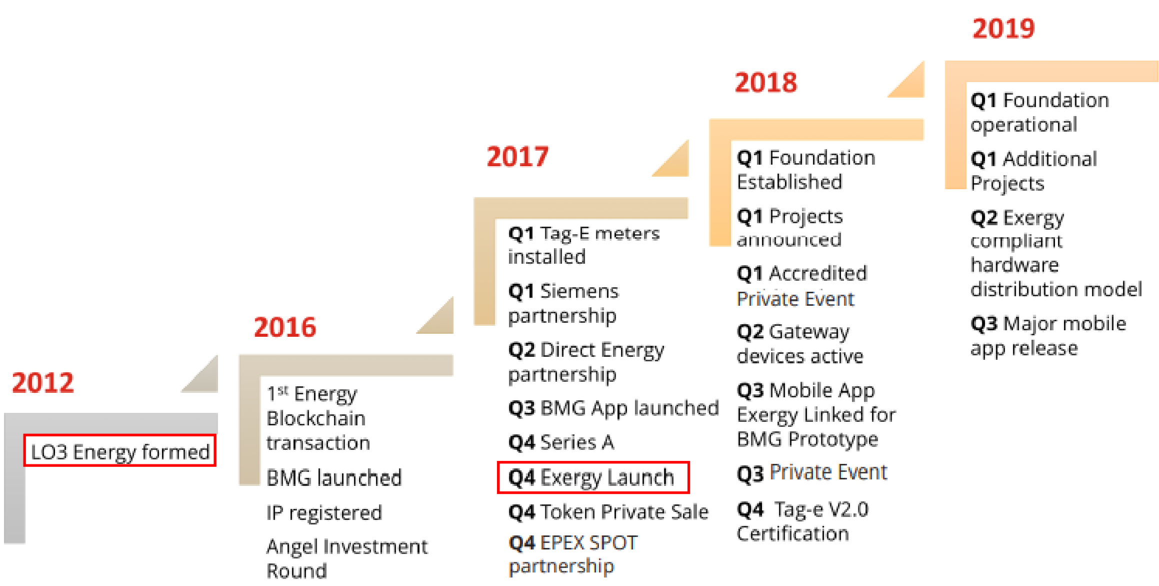


Figure 9: Roadmap Exergy solution (Exergy Whitepaper, 2018)

For energy system control, the distributed ledger must operate in tandem with real-world hardware rather than as a purely financial layer. LO3 Energy has created, manufactured, and deployed an Exergy-enabled IoT hardware device that serves as a distributed computer node and asset control switch. Figure 10 shows how the Exergy device operates peer-to-peer (LE2).
This device offers the control layer that translates economic signals from Exergy's TE layer into physical device control algorithms to enable market-desired local creation, storage, and operation of smart devices. Since early 2016, the Exergy distributed ledger system has been active on this Brooklyn hardware network and in cloud-based testing settings (LE2).

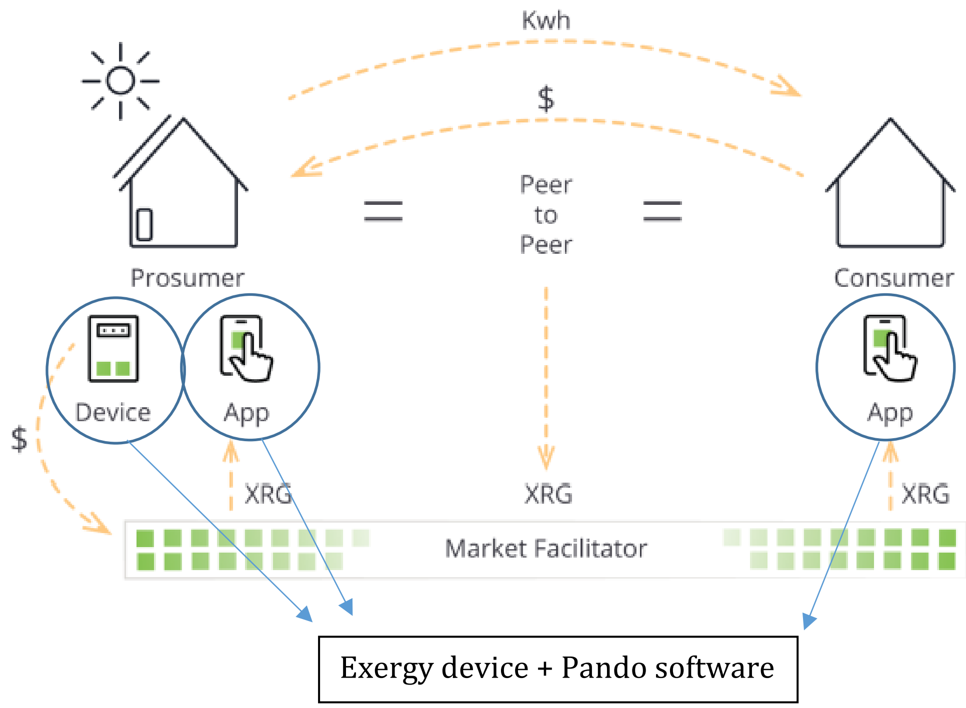


Figure 10: Peer-to-peer (P2P) energy use case Exergy device + Pando (Exergy Whitepaper, 2018)

Pando software records all the data obtained by the energy producer's device. In this way, within the marketplace, the energy producer can sell to the consumer in a peer-to-peer way. Thus, Pando's marketplace works as the connection between the producer and consumer. To give an idea, Figure 11 represents Pando's marketplace (LO5).

Figure 11: Pando's software marketplace platform (LO3, 2020)

In terms of competition, we found 2 main competitors, even though they are not operationally similar neither in the technology developed, the aim of these projects is quite similar as LO3 Energy.

- Suncontract: Suncontract is a blockchain-based P2P energy trading platform. Customers can buy and sell energy directly with one another nationwide, in the absence of intermediaries.
- Powerledger: Powerledger is the operating system for new energy markets enabling tracking and trading of energy, flexibility services and environmental commodities. They have developed an energy and flexibility trading platform that allows households, organisations and the grid itself to trade with each other.

LO3 energy has developed and partnered in interesting projects where it has contributed to the environment, here are a couple of good projects (LO2, LO5):

- Green Mountain Power: Vermont Green enables a subset of Green Mountain Power solar net-metered customers to assist their community in times of need. As bill credits, solar users provide a percentage of their exported generation to local businesses and customers with low to moderate incomes. This one-of-a-kind financial assistance initiative has contributed over $10,000 to the community thus far.
- Ameren: Ameren collaborated with LO3 and Washington University in St. Louis to implement a campus-based local energy market in 2020. The energy from solar panels on campus was pooled and distributed to university buildings according to specific market regulations. Students and teachers at WashU engaged in several market scenarios to evaluate price signal responsiveness and varied distribution results. Profitability of the university's solar installations is increased by optimizing consumption on campus.

Table 8: Summary Analysis LO3 Energy

Category	Analysis
Blockchain application	LO3 Energy operates with energy web blockchain network. It has developed two main digital solutions, Pando and Exergy. Both digital solutions utilize smart contracts. LO3 Energy has also implemented a token system for transactive energy.
SDGs Commitment	
Enhanced Collaboration	In terms of collaborations, L03 its collaborating with Shell, Bramar Energy Ventures, Centrica, Peci, Sumitomo corporation and Siemens.
Customers	Some of the companies that Energy web has in its customer portfolio are Iberia, Danone, Santander, Cabify, Mapfre, Melia Hotels, among others.
Revenue Stream	Some of the revenue streams of LO3 Energy is sale of smart devices, projects and installations, payment for consultations, among others.
Drawbacks	Given the importance of the energy sector, distrust is unlikely to be beneficial. However, the energy sector is one of the most regulated sectors by governments. There are many countries where the state provides energy to its citizens, and not the private sector is allowed. In this context, these projects could be a threat and considered competition due to the decentralization they offer. This could lead to new laws for the energy sector, limiting the implementation of blockchain technology in the energy sector. Another aspect to consider is that implementing a decentralized platform such as the marketplace developed by Energy web may not prevent private platform ownership from controlling the market and limiting democratic transparency.

Source: Author

Table 9: LO3 Energy – Overview of used sources

LE1	https://lo3energy.com/
LE2	http://www.truevaluemetrics.org/DBpdfs/Initiatives/Exergy/Exergy-2018-Business-Whitepaper-v10.pdf
LE3	https://bit.ly/3e5GTV9
LE4	https://www.smart-energy.com/industry-sectors/new-technology/transactive-blockchain-platform-updated-by-lo3-energy/

4.6.4 Project Case 4: Nozama

Nozama project is one of the projects that fall into the plastic pollution category and focuses on plastic recycling. Founded in London in 2019 by André L. Vanyi-Robin, Daniel Garcia Perez, and Trym Lyngset, it is a project that has grown exponentially and achieved remarkable goals in such a period. The company is an integrated sustainability applications and platform services company that enables companies to measure CO2 savings and kilograms of packaging recovered in a complete suite of data-driven tools that allow for sustainability marketing that is transparent and verifiable to increase customer loyalty (N4).

Nozama's mission is to ensure all CO2 emissions and Single-Use Packaging (SUP) are accounted for, compensated, and recovered. Neither CO2 emissions nor SUP are currently quantified or accounted for along the supply chain up to recyclers, and this prevents the measurement of the carbon footprint of the final consumer. After seeing this lack of traceability, André, Daniel, and Trym formed Nozama Green and developed several instruments for measuring and pricing sustainability. The business provides SaaS-based sustainability applications that monitor and monetize CO2 saved and SUP recycled. "PLASTIKS" is the platform they developed, and that is making possible their mission (N1).

The PLASTIKS platform is a blockchain-based application requiring a Plastik Tokens balance to track Single-Use Packaging production and consumption and establish accountability. The blockchain-based platform will integrate with existing information systems utilized by producers as well as waste recovery and recycling organizations. The Plastiks platform will give an approach to smart contracts for a marketplace where producers of single-use packaging and trash collection and recycling organizations may come together to mint, acquire, and sell plastic disposal guarantees analogous to NFTs based on the type of single-use packaging (N2).

Plastiks will enable the secure exchange of digital things between parties without requiring confidence or central authority. Figure 12 shows a representation of Plastiks platform from the producer of single-use packaging's perspective on Plastiks (the buyer). A buyer who wishes to acquire a single-use packaging recovered and recycled guarantee NFT (SUP) on Plastiks must own a digital wallet containing enough Plastik to either pay the fixed price for the SUP (if it has one) or pay for a winning bid in an auction for that SUP. The buyer of a SUP purchases the precise contract that proves the SUP is made from a certain type of recycled plastic (N2).
The buyer purchases the unique smart contract that guarantees the set amount of SUP will be recovered and recycled. To clarify, single-use packaging can be sold to producers of single-use plastics so that the plastic can be converted into a raw material that can be used to

create recycled plastic packaging. Similar to an NFT, only one SUP can be minted for every unit of recovered and recycled single-use packaging (N2).

From the perspective of a single-use packaging recovery and recycling company (the seller), PLASTIKS will enable the single-use packaging recovery and recycling company to mint single-use packaging recovered and recycled Guarantees and place them on the PLASTIKS platform. PLASTIKS will enable the secure exchange of digital things between parties without requiring mutual confidence or central authority (N2).
Each SUP's unique contract is saved on the peer-to-peer Binance Smart Chain.

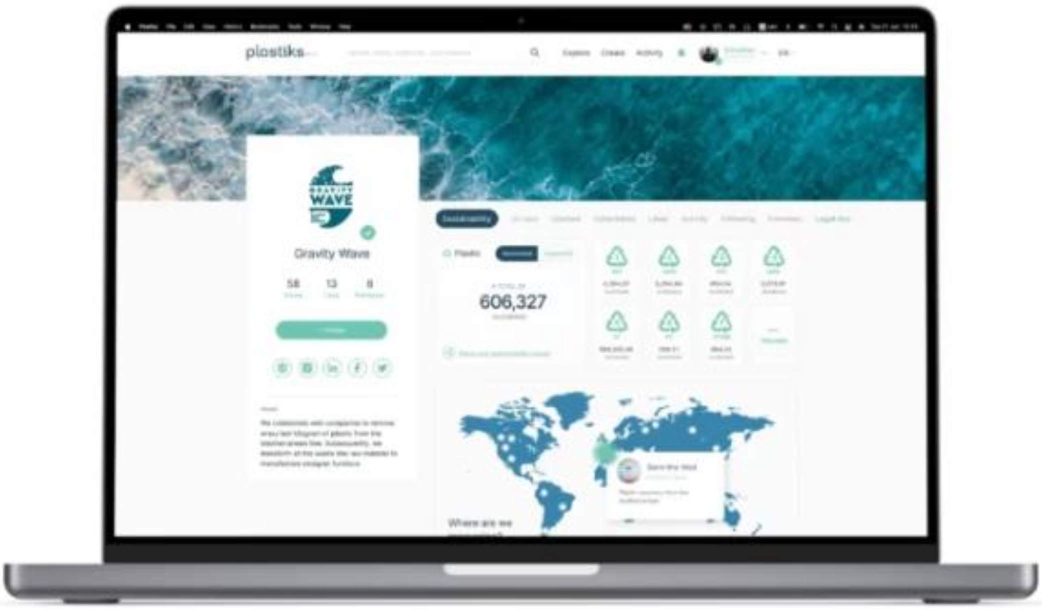


Figure 12: Plastiks platform (Plastiks, 2020)

Nozama project is the only project that uses Binance smart chain as its blockchain network in the list, and this is particularly interesting. The Case for Binance Smart Chain as the preferred network for Plastik Token issuance binance smart chain seeks to reduce transaction fees and provide a platform for the development of DApps and other Defi goods (N4).

Binance Smart Chain (BSC) is a blockchain network designed for hosting apps based on smart contracts. BSC operates concurrently with Binance's native Binance chain (BC), giving customers the best of both worlds: the huge transaction capacity of BC and the smart contract features of BSC (N5).
In addition, Binance Smart Chain implements the Ethereum virtual machine (EVM), allowing it to execute Ethereum-based applications such as MetaMask.
The objective of the platform is to allow developers to create decentralized applications (DApps) and assist users in managing their digital assets cross-chain with low latency and high capacity (N5).
Due in part to Ethereum's congestion and gas tax difficulties, which have prompted developers and stake investors to seek alternative solutions, Binance Smart Chain has garnered massive interest since the beginning of 2021. To offset Binance Coin (BNB) price increase to over $300 in February 2021, the BSC community reduced the network's gas fee from 15 Gwei to 10 Gwei, making it more attractive to new users as a cost-effective and stable alternative (N2).

In terms of competition, we found two main competitors. Even though they are not operationally similar nor in the technology developed, the aim of these projects is quite similar to Nozama.

- Oxyn: This project acts as a solution to the problems of plastic pollution and waste; it is a cryptocurrency and blockchain ecosystem that allows you to effortlessly send packages back to the manufacturer for re-use purposes, to help eliminate plastic pollution.
- Plastic Bank: Plastic Bank is a social enterprise with a goal to use recycling to reduce plastic in the ocean and fight global poverty. Plastic Bank pays people to collect plastic, thereby preventing it from getting into the ocean.

Nozama's project has a remarkable social and environmental impact. Currently, it has three large enterprise customers and more than 50 small and mid-sized customers. For instance, Geneva Business School has partnered with Nozama to achieve environmentally sustainable goals.

Geneva Business School uses case.

Nozama distributes goods bought via their app, collects your recycling to sort at their recycling plant, and then sells as inputs for new products. Nozama solely sells recyclable products so that its consumers may consume responsibly, knowing that their purchases will not negatively impact the environment due to their everyday usage (N3).

Nozama's business has grown dramatically since COVID-19 pushed everyone indoors. They currently serve the entire province of Barcelona, having begun in a tiny area in the city center. This service addresses the need for home-delivered goods and the fact that we must remember to live sustainably, avoid waste, and do our part for the environment even in times of crisis (N3).

Over the past year, Geneva Business School has ordered campus supplies, office kitchen items, and event catering. Nozama delivers weekly items such as tea and recyclable coffee pods, pantry necessities, and cleaning supplies on foot, electric scooters, bicycles, or electric motorcycles, and collects discarded packaging. Nozama Green then separates and sends the recyclable materials to recycling factories, which are processed into new products (N3).

Nozama's business approach emphasizes social impact and collaborates with the non-profit organization #HomelessEntrepreneur. They employ homeless individuals as part of their program so they can once again be productive members of society. These individuals sort recyclables at the sorting center, which gives them a sense of accomplishment while also providing them with a purpose and an income (N3).

As part of the 2030 UN Sustainable Development Goals, Geneva Business School is committed to developing effective, accountable, and inclusive leaders who will contribute to the sustainable development of future societies. Aligning with small enterprises such as Nozama is essential for demonstrating to the student's effective local solutions to global problems and providing them with models of innovative and responsible leadership (N3).

Table 10: Summary Analysis Nozama

Category	Analysis
Blockchain application	Nozama has developed a blockchain-based platform called Plastiks, through this platform users can exchange single-use goods for Plastiks tokens, this is possible due to the implemented token system by Nozama. Plastiks platform utilizes smart contracts for its operation.
SDGs Commitment	
Enhanced Collaboration	In terms of collaborations,Nozama has partnered with Lbank, Gravity Wave, Coin Market Cap, among others.
Customers	Unkown
Revenue Stream	Some of the revenue strems of Nozama is the sale of Plastiks platform, installation, data as a service, among others.
Drawbacks	The main issue we can find in working with the tokenization system as the core of its operation is having to authenticate external data to operate exacerbates the problem of mistrust. Generally, democratic openness has been disregarded. Secondly, the token must have a value to represent a social good, and there must be a real demand for it. The tokenization system depends greatly on external actors willing to incentivize sustaina-bility practices.

Source: Author

Table 11: Nozama – Overview of used sources

N1	https://nozama.green/
N2	https://plastiks.io/wp-content/uploads/2021/11/Plastiks1.6_white_paper-1.pdf
N3	https://gbsge.com/en/news/newsroom/newsroom/nozama-green-powers-circular-economy/
N4	https://www.youtube.com/watch?v=Dh4k-1Udkfk&t=1988s&ab_channel=BlockStart
N5	https://www.blockchain-council.org/cryptocurrency/binance-smart-chain/

4.6.5 Project Case 5: Plastic Bank

Plastic Bank is the other project that falls into plastic pollution category and similarly as Nozama project it focuses in plastic recycling. Founded in Vancouver, Canada in 2013 by David Katz and Shaun Frankson is by far the best-established project, they are the market leaders and have a tremendous impact in social media in this category. Plastic Bank enables people living in poverty to collect plastic and exchange it for material items such as school tuition, medical insurance, pharmaceutical access, internet connection, and cooking fuel, with the goal of expanding their program in the future to include additional benefits. Plastic Bank reintroduces recycled plastics into the supply chain. They presently have operations in the Philippines, Indonesia, Brazil, and Egypt, with future expansion ambitions in Colombia and Vietnam. Figure 13 shows some milestones of Plastic Bank (PB2, PB4).

David Katz and Shaun Frankson had an innovative and disruptive idea of how incentive people for recycling, that is how was born Plastic Bank. The idea was to convert plastics into a currency for underprivileged communities. Katz initially conceived of their business strategy in an arcade where consumers exchanged tickets for rewards. Using this concept, he devised a system that assigned the same value to what individuals waste, so generating a currency that could be exchanged for material products or services (PB1).

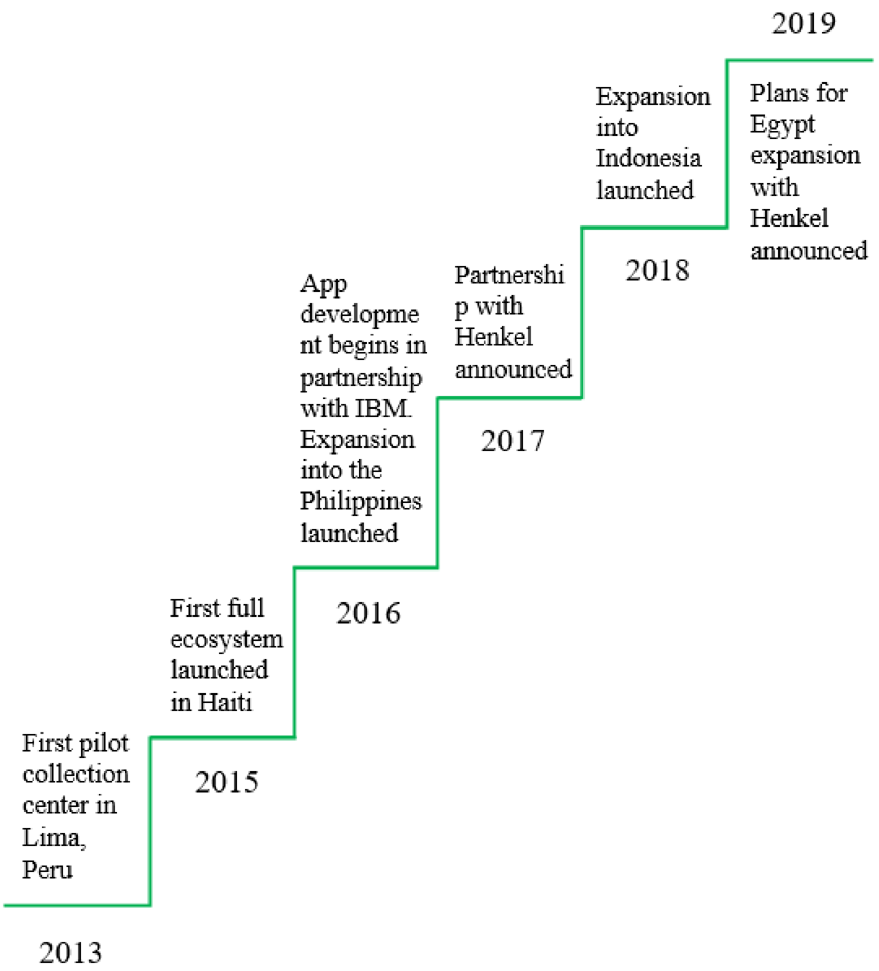


Figure 13: Plastic Bank milestones (Plastic Bank, 2020)

To turn the tide on ocean plastic and help alleviate global poverty, Plastic Bank sought technology and skills that would enable rapid innovation and inspire confidence. Plastic Bank believed IBM blockchain was the perfect network to work with. Using IBM technology and agile development from IBM Business Partner Cognition Foundry, Plastic Bank is developing the gold standard for ethical, traceable, and exponentially scalable supply chains. IBM Blockchain, running on a hybrid cloud infrastructure based on an IBM LinuxONE platform connected to IBM CloudTM, drives the global Plastic Bank revolution. Cognition Foundry, an IBM Business Partner, created and manages the environment, which offers creative startups access to enterprise-level resources (PB3).

Plastic Bank, in collaboration with Cognition Foundry, developed a Blockchain platform that secures every transaction and enables real-time data visualization. It offers a verifiable audit trail along the whole value chain, from the time a member contributes plastic garbage to a branch to the time Social Plastic is reintroduced into a new product. Plastic Bank meets regularly with Cognition Foundry to design updates to the Plastic Bank application and associated infrastructure technologies (PB3).

This blockchain technology enables traceable collection, secures income and verifies reporting from the initial plastic collection in the communities through to the products manufactured with Social Plastic feedstock that are available on supermarket shelves around the world (PB1).

In terms of competition, we found 2 main competitors, even though they are not operationally similar neither in the technology developed, the aim of these projects is quite similar as Plastic Bank.

- Oxyn: This project acts as a solution to the problems of plastic pollution and waste; it is a cryptocurrency and blockchain ecosystem that allows you to effortlessly send packages back to the manufacturer for re-use purposes, to help eliminate plastic pollution.
- Nozama: Previously analyzed in this paper, it is a blockchain based platform to track and create accountability for single use packaging production and consumption. The blockchain based platform will connect to existing information systems that are being used by companies who are producers and by waste recovery and recycling companies.

The environmental and social impact of Plastic Bank is tremendous. Plastic Bank's objective is to reduce ocean plastic by uniting a billion individuals to monetize trash while improving lives. The group has received numerous humanitarian awards for its efforts to alleviate environmental devastation and global poverty.

Plastic Bank is constructing new recycling ecosystems that adhere to ethical standards in numerous coastal towns. The organization established its initial branches in Haiti, the Philippines, and Indonesia, and has lately begun activities in Brazil and Egypt. Members who collect plastic are rewarded with digital tokens redeemable for groceries, cooking fuel, school tuition, health insurance, and more through the Plastic Bank app. As part of a closed-loop supply chain, the processed 'Social Plastic' is re-incorporated into products and packaging (PB4).

Today, Plastic Bank has executed over one hundred thousand transactions at around two hundred and eighty locations, with exponential growth on the horizon. Plastic Bank aspires to maximize its beneficial influence on the communities in where it operates and to forge new collaborations as it expands (PB1).

Plastic Bank claims that they have collected approximately 55.9 million kg of plastic through over 21,730 collectors in its four nations as of the year 2020. This amount of plastic, according to the business, is comparable to more than 2,796,837,796 plastic water bottles. Plastic Bank has placed collection bins in schools to encourage pupils to recycle from an early age. In addition, "Plastic Bank Ambassadors" are employed to promote environmental education in Haiti (PB1).

Table 12: Summary Analysis Plastic Bank

Category	Analysis
Blockchain application	Plastic bank has developed a platform where you can exhange plastic collected for native tokens and these tokens can be exhange for other goods. Plastic bank uses smart contracts as well.
SDGs Commitment	
Enhanced Collaboration	In terms of collaborations, Plastic bank has partnered with IBM
Customers	Some of the companies that Plastic bank has in its customer portfolio are 3M, Henkel, Coca Cola, Aqua sale, Metro, ScJohnson, among others.
Revenue Stream	In a nutshell the way that Plastic bank generate revenue stream is that plastic collectors exhange the plastic with plastic bank and plastic bank sell these platics to companies and issue an environmental certificate
Drawbacks	The main issue we can find in working with the tokenization system as the core of its operation is having to authenticate external data to operate exacerbates the problem of mistrust. Generally, democratic openness has been disregarded. Secondly, the token must have a value to represent a social good, and there must be a real demand for it. The tokenization system depends greatly on external actors willing to incentivize sustaina-bility practices.

Source: Author

Table 13: Plastic Bank – Overview of used sources

PB1	https://plasticbank.com/
PB2	https://en.wikipedia.org/wiki/Plastic_Bank
PB3	https://www.ibm.com/case-studies/plastic-bank-systems-linuxone
PB4	https://bit.ly/3ABft0U

4.6.6 Project Case 6: Regen Network

Regen Network is the only project that falls into land preservation category, it is an innovative project that seeks to stop ecological degradation and climate change. Founded in 2017 by Gregory Landua Regen Network aims to reinvent the economics of agriculture so that farmers are seen not only as food producers, but also as land stewards. Using remote sensing and distributed ledger technology, Regen Network aims to expand the Payments for Ecological Services market in a way that compensates farmers for ecological practices with positive ecological outcomes, while enabling corporations to improve their supply systems, municipalities to reduce their risk of climatic disasters, and governments to meet their environmental obligations regarding water, carbon, and more (RN1).

To achieve this ambitious goal Regen Network, seek for the technology which can make it happen, blockchain technology seemed to be the answer. Both transparently tracking ecological data and incentivizing shifts in land use toward more regenerative practices are enabled by blockchain technology. It is also a suitable technique for encouraging collaboration among varied stakeholders who eventually share goals but may not be as willing to work together. Through the Regen Consortium and the community staking pools, they hope to foster a culture of collaboration in order to construct the infrastructure required to raise humanity's knowledge of and ability to address Earth's problems. The implementation of blockchain in the real world to construct a global ecological accounting system and unlock the potential to reward improvements in ecosystem health is essential for developing a coordinated response to climate instability, soil depletion, and biodiversity loss (RN3, RN4).

Regen Network core attributes to operate are smart contracts and tokenization. For market-driven solutions to produce regenerative outcomes, commercial and public sectors must have access to comprehensive ecological accounting. The capacity of blockchain to tokenize the protocol or infrastructure layer of information technology and the internet is one of its major advancements. This is crucial because it enables the emergence of a new economic model in which open source, cooperative, distributed innovation is possible and required to sustain and raise the value of the token representing access to the underlying infrastructure. By tokenizing the common asset or infrastructure upon which economically generative (and in the case of Regen Network, ecologically regenerative) applications can be built, it becomes possible to make the evolution and development of this core infrastructure not only viable, but also appealing to developers and investors. REGEN, the native token of Regen Ledger, will provide the ability to cooperate on the development of ecologically responsible information technology infrastructure (RN2).

The basic characteristics of Regen Ledger's design, as well as the objective of the larger Regen Network community, is the power to use smart contracts to incentivize ecological regeneration. Figure 14, shows the system architecture more detailed the and the most efficient way to design a system for trusted ecological state attestations based on verifiable ecological data (RN2).

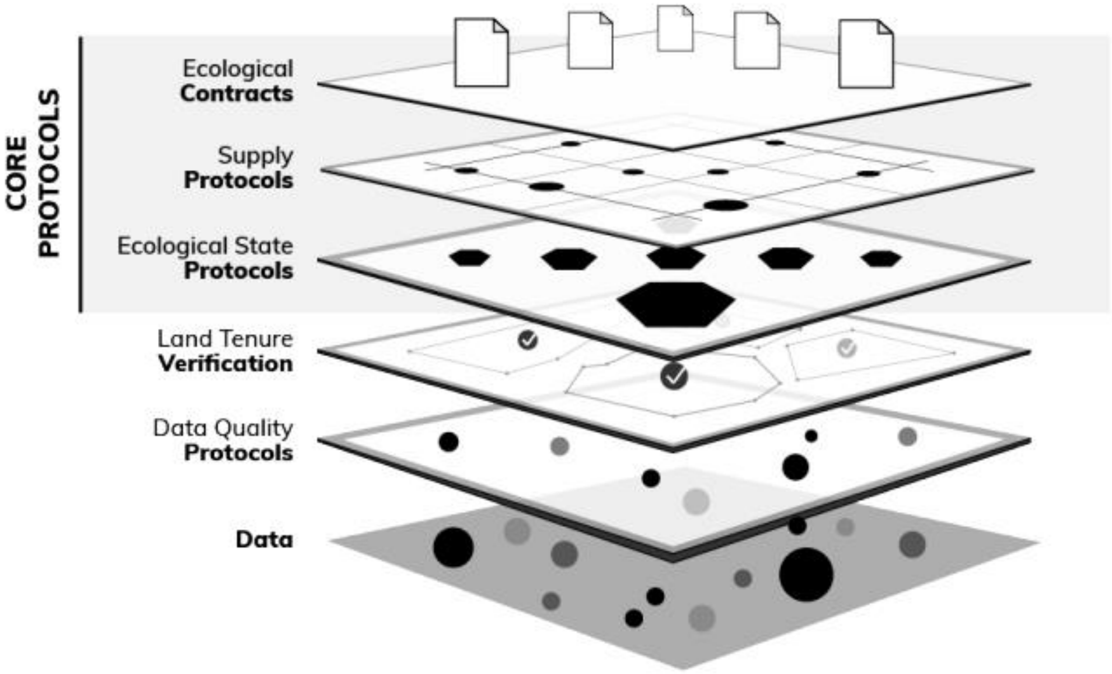


Figure 14: Regen Network system architecture (Regen Network whitepaper, 2017)

Regen Network claims to offer to the world the following advantages (RN2):

- Community-centric: Incubating ecological-impact DAOs and new methodology development with scientists, project developers, and climate impact researchers.
- Tokenize Carbon Credits: Mint, retire, and transfer new digital ecological assets and create asset baskets with Regen Registry and Regen Marketplace.
- Decentralization: Regen Network matches land steward stakeholders with the governance of a layer 1 blockchain dedicated to ecological health and climate action.

In terms of competition, we found 2 main competitors, even though they are not operationally similar neither in the technology developed, the aim of these projects is quite similar as Regen Network.

- Rewilder: Rewilder is a crypto-native non-profit that coordinates the global purchase of land for wildlife conservation.
- Basin: Also known as the "project developer" DAO, basin works at the real property level building and executing climate, nature and carbon projects with an emphasis on "core benefits" such as biodiversity, ecosystem services and climate resilience.

There several interesting projects that Regen Network is working on that are impacting significantly the communities and environment. For instance, Eco Cacao project started in Ecuador. In the initial phase of this pilot program, they are collaborating with high-end chocolate businesses in California, such as Imlak'esh Organics and Endorfin Foods, as well as Eco Cacao and its parent organization UOPRACAE, a cooperative of roughly 120 farmers from the Esmeraldas region in Ecuador. They intend to expand this initiative to thousands of cacao farmers globally (RN1).

Terra Genesis International, their partner in executing this pilot, has helped Eco Cacao train their farmers in regenerative practices and establish the first regenerative cacao certification (RN4).

Regen Network approach for this project was using remote sensing verification, Using the remote sensing-based algorithms supplied by Regen Network, Eco Chocolate can validate their use of polyculture as opposed to monoculture approaches on cacao farms. Additionally, other land cover classes relevant to land use management and the health of ecosystems may now be recognized with high precision and provide additional insights into the vegetation cover of each farm (RN1).

Large-scale verification of regenerative methods within tropical agroforestry systems can be accomplished with minimal expense using remote sensing. In addition, project-based funding with customized verification can give an alternate method for funding this essential regenerative activity. This initiative helps the financial well-being of farmers and producers as well as the viability of communities in Ecuador, where cocoa growers frequently deal with poor margins, development pressure, and rising climate-related risks and expenses. This project incentivizes a move toward ecologically sound activities, resulting in healthy land, cleaner water, cleaner air, and climate change mitigation (RN2).

Future program development will concentrate on streamlining the verification process, increasing market demand for regenerative cacao, and creating incentives for landscape-scale regeneration based on a broader suite of land management practices that include conservation and restoration priorities as well as various forms of regenerative agricultural production (RN1).

Table 14: Summary Analysis Regen Network

Category	Analysis
Blockchain application	Regen network has developed a platform that enables transparently tracking ecological data and incentivizing shifts in land use toward more regenerative practices by blockchain technology. Tokenization systems and smart contracts are the main blockchain applications.
SDGs Commitment	
Enhanced Collaboration	In terms of collaborations,Regen network has partnered with The Provenance Co, Impact Ag Partners, Wildlife Works Carbon LLC, among others.
Customers	Individual users
Revenue Stream	One of the revenue streams for Regen network is a comission for using its platform.
Drawbacks	The main issue we can find in working with the tokenization system as the core of its operation is having to authenticate external data to operate exacerbates the problem of mistrust. Generally, democratic openness has been disregarded. Secondly, the token must have a value to represent a social good, and there must be a real demand for it. The tokenization system depends greatly on external actors willing to incentivize sustaina-bility practices.

Source: Author

Table 15: Regen Network – Overview of used sources

RN1	https://www.regen.network/
RN2	https://regen-network.gitlab.io/whitepaper/WhitePaper.pdf
RN3	https://solarimpulse.com/companies/regen-network
RN4	https://green.org/2022/02/10/regen-network-developing-a-platform-for-a-thriving-planet/

5 Discussion and results implications

In this chapter, the outcomes of the research are discussed. The aim of this chapter is to answer the research question that we stated at the beginning of this paper.

It is evident that blockchain is a disruptive technology that is rapidly expanding, and it is beginning to come out from the financial, insurance, and manufacturing world to explore the environmental sustainability sector. The impact of blockchain technology on sustainability may be crucial to achieving sustainability goals. After analysing the six final projects, the results showed that each case project has more than one sustainability goal targeted, the sustainability goals targeted vary from project to project, and each project has its mechanisms of application of blockchain technology. However, the primary focus area of the project indicates a similarity in the sustainability goals targeted as well as the mechanisms of application of blockchain technology. Table 16 shows the results of the sustainability goals targeted by case projects.

Table 16: Sustainability goals targeted by case project

	SDG1*	SDG2*	SDG6*	SDG7*	SDG11*	SDG12*	SDG13*	SDG14*	SDG15*
Project Case 1: ClimateTrade	✓	✓					✓	✓	✓
Project Case 2: Energy web				✓	✓		✓		
Project Case 3: LO3 Energy				✓	✓		✓		
Project Case 4: Nozama					✓	✓	✓	✓	✓
Project Case 5: Plastic bank			✓				✓	✓	✓
Project Case 6: Regen network		✓				✓	✓		✓

**SDG1: No poverty*

**SDG2: Zero hunger*

**SDG6: Clean water and sanitation*

**SDG7: Affordable and clean energy*

**SDG11: Sustainable cities and communities*

**SDG12: Responsible consumption and production*

**SDG13: Climate action*

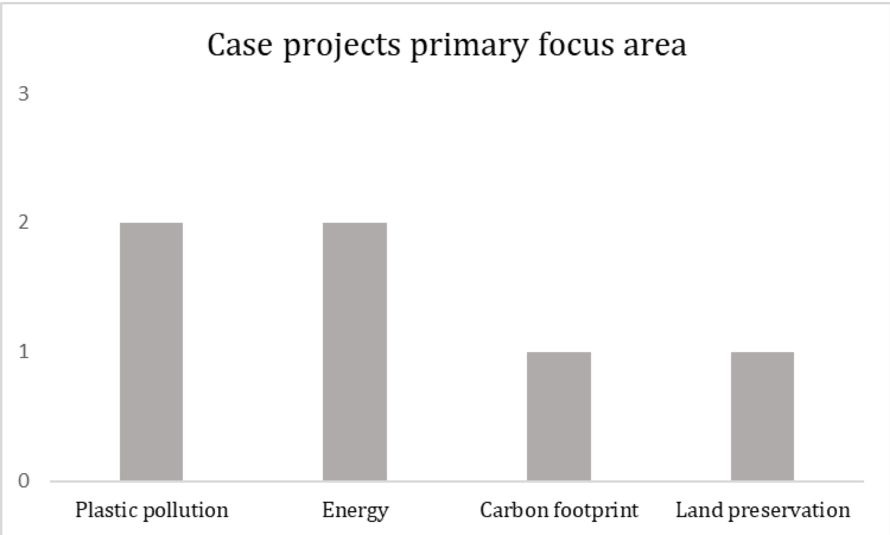
**SDG14: Life below water*

**SDG15: Life on land*

Source: Author

The sustainability goal most targeted was "Climate action," with all the case projects targeting it, which should not be surprising. According to a study by Accenture and UN Global Compact, the most sustainability goal targeted by companies is Climate action, followed by affordable & clean energy and sustainable cities and communities (SDGs: The 3 Most Popular Goals for Business, n.d.). "Life of land" was the second sustainability goal most targeted by the case projects, ClimateTrade, Nozama, Plastic Bank, and Regen Network targeting it. "Life below water" and "Sustainable cities and sustainable communities" were the third most targeted goal.

In total there were four primary focus areas analysed from the case projects, Figure 15 shows the case project categories.



Source: Author

Figure 15: Case projects primary focus area

5.1 Blockchain application for plastic pollution category

Nozama and Plastic bank are the case projects that fall in this category. They have similar sustainability goals, such as climate action, life below water, and life on land. The application of blockchain technology in these projects to achieve those sustainability goals is the same, smart contracts, tokenization systems, and blockchain technology as data storage. The idea of applying a tokenization system seeks to incentivize sustainable action by producers and consumers, in this case, by collecting plastic pollution and recycling. Both projects developed a marketplace platform where native tokens can be exchanged for social goods. By assigning a monetary value to these tokens, the projects intend to encourage users to produce more of them and thus take more sustainability actions. Smart contracts are another blockchain application applied to the plastic pollution category. Chapter 2 explains how smart contracts work. Nozama and Plastic bank apply smart contracts in several ways. They can issue a certificate for achieving am amount of plastic collected. At the moment of the exchange between plastic collected and tokens, a smart contract is also being applied for the exchange of tokens to social goods with the benefit of a more decentralized exchange within their marketplace. Lastly, blockchain technology offers a safer way to store data and better traceability than the current applications, this can prevent data manipulation from companies, and this generates more confidence in data management and the progress that has been made in achieving sustainability goals from companies.

5.2 Drawbacks blockchain application for plastic pollution category

A tokenization system to reward and incentive people to clean water and land by collecting waste plastic and recycling sounds like a good and innovative idea. However, the main issue we can find in working with the tokenization system as the core of its operation is having to authenticate external data to operate exacerbates the problem of mistrust. Generally, democratic openness has been disregarded. Secondly, the token must have a value to represent a social good, and there must be an actual demand for it. The tokenization system depends on a lot of external factors that are willing to incentivize sustainability practices. Although smart contracts strive to eliminate the involvement of third parties, it is hard to do so. For instance, lawyers will not be required to draft individual contracts, but they will be required to comprehend the conditions to build codes for smart contracts.

5.3 Blockchain application for energy category

Energy web foundation and LO3 energy are the case projects in this category. They have the same sustainability goals, such as affordable and clean energy, sustainable cities and communities, and climate action. The applications of blockchain technology to achieve those goals are practically the same. These projects intend to be decentralized energy trading platforms, lowering the entry barriers for 'prosumers' of electricity to produce renewable energy and sell surpluses. Smart contracts play a crucial role in this process by making possible the contract exchange without a third-party interfering. This is intended to encourage the widespread adoption of renewable energy and make it easier for consumers to purchase renewable energy at a reasonable cost. In addition, Energy web foundation has developed its blockchain for the energy sector, which is presumed to be the most used, with the minor energy consumption to operate and the most favourable blockchain in this sector. LO3 energy operates with energy web blockchain.

5.4 Drawbacks blockchain application for energy category

Decentralized energy trading is desirable nowadays, and it could exponentially increase renewable energy use. However, the energy sector is one of the most regulated sectors by governments. There are many countries where the state provides energy to its citizens, and not the private sector is allowed. In this context, these projects could be a threat and considered competition due to the decentralization they offer. This could lead to new laws for the energy sector, limiting the implementation of blockchain technology in the energy sector. Another aspect to consider is that implementing a decentralized platform such as the marketplace developed by Energy web or LO3 energy may not prevent private platform ownership from controlling the market and limiting democratic transparency.

5.5 Blockchain application for carbon footprint category

ClimateTrade is the only case project that falls into this category. It is the case project that targets more sustainability goals. Climate trade seeks to fight climate change by offsetting CO2 emissions. To achieve this, Climate trade uses blockchain technology to store and track user data. The advantages of using blockchain technology for tracking C02 emissions are several. Applying this technology to the world of environmental clearing achieves the ultimate traceability in these operations. Because thanks to the multinodular information storage system, its transparency and speed are multiplied. Smart contracts are being used to compensate for the tracking of C02 emissions.

5.6 Drawbacks blockchain application for carbon footprint category

The idea of tracking C02 emissions and compensating it to encourage sustainability practices sounds doable and desirable. To do that, there must be a digital platform that makes that possible. However, the implementation of a decentralized platform such as the marketplace developed by Climate Trade may not prevent private platform ownership from controlling the market and limiting democratic transparency. In addition, from a business perspective, achieving total transparency might not be attractive.

5.7 Blockchain application for land preservation category

Regen Network is the only case project that falls into this category. It targets four sustainability goals. The application of blockchain technology is quite similar to the plastic pollution category. The use of blockchain technology as data storage, tokenization system, and smart contracts are the primary applications. Regen Network incentivizes with native tokens regenerative land use practices, restores ecosystems, and reverses climate change through the marketplace they developed. With blockchain technology is possible to make ownership information accessible, traceable, and secure. By incentivizing people to restore the ecosystems, sustainability practices, and reverse climate change, they seek to tackle the environmental issues and achieve sustainability goals.

5.8 Drawbacks blockchain application for land preservation category

As discussed previously, the main issue we can find in working with the tokenization system as the core of its operation is having to authenticate external data to operate exacerbates the problem of mistrust. Generally, democratic openness has been disregarded. Secondly, the token must have a value to represent a social good, and there must be a real demand for it. The tokenization system depends greatly on external actors willing to incentivize sustainability practices.

5.9 Blockchain Laws and Regulations

First of all, it is important to clarify that we are not talking about cryptocurrencies. We are talking about blockchain technology. Some people can misinterpret these concepts. Regarding the regulation of blockchain technology in governments, it seems to be a bright future for the adoption of this technology. European and North America regions are the pioneers in adopting blockchain technology in different sectors, including environmental sustainability. In fact, most of the blockchain projects were founded in these regions. The European Commission stated the following regarding blockchain:

> The European Blockchain Partnership is planning a pan-European regulatory sandbox in cooperation with the European Commission for use cases in the EBSI and outside of EBSI, including for data portability, business-to-business data spaces, smart contracts, and digital identity. This will cover sectors including health, environment, mobility, energy and more (Legal and Regulatory Framework for Blockchain, 2022).

The energy sector for environmental sustainability is one of the sectors most likely to be regulated. A decentralized energy trade platform sounds attractive to consumers, and by encouraging the use of renewable energy, these projects could make a tremendous impact on sustainability in governments where there is a free energy market and not a monopoly in the sector. In contrast, there are many countries where the energy sector is provided by the state. Therefore, these projects could be a threat, and eventually, a regulation to be placed is more likely to happen.

Although there is now a great deal of uncertainty on how regulators will approach the blockchain business, the long-term view is optimistic. Each new regulatory action gives clarification for the sector, and this clarity enables participants to better coordinate their actions and plan for the blockchain technology industry's bright future, which eventually will make a positive impact on environmental sustainability.

5.10 Implications

The conclusions of the research and the knowledge gained during its conduct have a number of implications for researchers, business owners, NGOs, and managers. These suggestions and comments finish the chapter.

This thesis provides business owners with empirical evidence that may serve as a deciding factor for blockchain adoption. On a sample of six projects, it was demonstrated that blockchain is highly disruptive and appropriate. On this strategic and tactical management level, where decisions regarding future investments in information systems are made, it can therefore serve as a guide. Companies, NGOs, and managers are not required to develop new blockchains, but they may consider if it makes sense to join the platform analysed in this study. It was mentioned for whom these solutions are intended; thus, practitioners may take inspiration from this and choose whether joining such a platform is reasonable. In addition, developers could take into account the issues outlined in this thesis and alter the development accordingly. This research has no business purpose. Thus, deeper research to understand blockchain technology and projects is necessary for business decisions.

For researches can be handful the information provided in this thesis, it was described that different cases use different business models for blockchain adoption in environmental sustainability. However, due to the scope of this research, certain areas are not covered enough. This can be an opportunity for a researcher to continue with the research and go deeper into the projects.

5.11 Limitations

Consideration must be given to the limitations of this research. Initially, this thesis examines the blockchain from a broad perspective, and it does not differentiate between various technological blockchain types. This would have led to more precise results. It is consequently advised that further studies concentrate primarily on developed applications. For instance, blockchain projects for environmental sustainability in the energy sector or carbon footprint.
Secondly, the business models and objectives of the case studies vary, and blockchain is utilized for a variety of purposes differently included in the product. Consequently, it may be misleading to evaluate.
Thirdly, the primary sources utilized in case study analysis are frequently unilateral orientated, which may result in less objective results. Such sources as articles are frequently published on websites that focus on blockchain or cryptocurrency; thus, their viewpoint may be less critical. These websites provide excellent coverage of new alliances and milestones. However, with the help of blockchain's hype, they may tend to present blockchain applications in slightly better condition than they are.
Fourthly, some data was acquired from corporate reports, which provide significant information concerning their references. It may not always be objective due to their inherent

desire to present themselves admirably. Alternatively, they frequently quoted their customers, which makes it less subjective. In addition, considering most projects are in the start-up face, much information is lacking, such as the revenue streams.

6 Conclusion

The aim of the present thesis was to examine the role of blockchain technology in environmental sustainability. Approximately 29 case studies with blockchain applications aimed at environmental sustainability have been identified, and only six of those have passed the criteria for further analysis.

In the literature review chapter, the theoretical background is presented. Firstly, the history of blockchain technology, then the basics of blockchain, as well as technical concepts. Secondly, an introduction to sustainability and environmental sustainability followed by the challenges and the link between blockchain and environmental sustainability. The final section was devoted to current research, which supported the research statement of the thesis.

The following chapter on methodology explains why the case study research design and simplified content analysis were chosen. In addition, the prerequisites for conducting a rigorous exploratory case study were outlined, and the author demonstrated how this thesis meets those requirements. 29 blockchain projects were presented in chapter 4. Six of them were selected for further analysis based on some selection criteria and subsequently analysed. Chapter 5 concludes with a review of the results, the implications of the research, and its limitations.

It can be concluded that this thesis contributes to the existing academic literature by presenting current information on blockchain projects for environmental sustainability. Moreover, the research results reveal numerous prospects for further study and implications for researchers, business owners, companies, NGOs, and managers. They can gain closer insights and consider involvement and investment in blockchain-related activities. Or even become a user or customer from the projects analysed. In addition to addressing the research questions, the thesis offers additional information concerning the project's scope, future development, and adoption process and other pertinent information mentioned within the scope within the extent of the Analysis chapter.

Given the immaturity of blockchain technology, there is still much to learn about it, and environmental sustainability practitioners have substantial room for expansion. As the majority of prior research focused on what blockchain could do and the promising characteristics of this technology, the purpose of this thesis was to describe what blockchain has already accomplished and how it has been accomplished. Future research in these areas is strongly encouraged

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