

A Work Project for obtaining the Master's degree in Finance from the Nova School Of
Business and Economics.

**A Quantitative Inquiry into Market Trends, Costs, and Regional Dynamics: Shedding
Light on the Voluntary Carbon Market Through Rigorous Data Analysis and
Comparative Exploration**

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Abstract:

This work project presents a comprehensive analysis of the voluntary carbon market, exploring dynamics and frameworks while emphasising the transformative impact of blockchain technology in enhancing transparency and credibility. Conducted in partnership with Celfocus, the research delves into the challenges and potential opportunities within the market, offering novel insights for stakeholder perspectives. Detailing qualitative and quantitative data on the historical market context, the study underscores the market's critical importance in reducing carbon emissions. The findings offer valuable contributions to understanding market mechanisms, associated costs, and possible investment outlooks and opportunities in Europe.

Keywords: Voluntary Carbon Market, Blockchain, Carbon Credits, GHG emissions, Carbon Market

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1 Introduction

1.1 Field Lab Specification

This Field lab project focuses on the in-depth study of one of the mechanisms built to combat climate change and to reduce the emission of Greenhouse Gases (GHG), the voluntary carbon market. The project fits within the scope of the BLOCKCHAIN.PT initiative, which forms a part of the "Decentralize Portugal with Blockchain" agenda and is backed by funding from the European Union's NextGenerationEU program. This project's genesis lies in forming a consortium which successfully secured acceptance into Portugal's resilience recovery plan (RRP). Among various collaborators, Nova has joined this consortium and opened the opportunity for master's students to participate. In collaboration with Celfocus, the project team has been assigned to investigate and develop a blockchain-driven platform explicitly designed to facilitate the voluntary carbon market and the transaction of carbon credits.

This undertaking coincides with Portugal's legislative initiatives to establish a Voluntary Carbon Market (VCM). The Minister of Environment and Climate Action Duarte Cordeiro has emphasised the imperative of achieving carbon neutrality by stating, "To attain carbon neutrality, we must not only address emissions but also enhance the capacity of the country's carbon sinks." This national VCM initiative, including this specific project, will contribute to devising strategies and frameworks to attain the goal of carbon neutrality by 2050 (Duarte Cordeiro, 2023).

1.2 Climate Change: the global challenge that needs to be tackled

Climate change is a current global problem, and its control started in the seventies when environmental law began to appear, such as the Clean Air Act in the United States of America, followed by the first reports on the importance of climate change in the early nineties. It was not until 1997 that the world saw a collective effort by countries to mitigate climate change in an initiative known as the Kyoto Protocol (United Nations, Dec. 10, 1997). Countries under this

protocol must meet targets for greenhouse gas emissions, primarily through national measures. Otherwise, countries will be exposed to a "carbon tax" if they exceed emissions. To that end, three market-based solutions emerged: the International Emissions Trading System (ETS), the Clean Development Mechanism (CDM), and the Joint Implementation (JI), known as Compliance Carbon Markets. These solutions led countries to invest in carbon removal or avoidance projects, which would count towards their nationally determined contributions (NDCs). However, the surplus of emissions removed or avoided was transformed into what today is called carbon credits and traded in market-based solutions.

In recent years, the solutions brought by the Kyoto Protocol have been re-evaluated in the Paris Agreement (United Nations, Dec. 12, 2015) to provide financing to developing countries to mitigate climate change, strengthen resilience, and enhance the ability to adapt to climate impacts. The Paris Agreement brought new global targets, including cutting all GHG emissions by 2050 (net zero) and limiting the global temperature variation below 1.5 degrees Celsius. Article 6 of the Paris Agreement was essential, as it allowed the voluntary cooperation of countries on the international trade of credits, which enabled the scale of the Voluntary Carbon Market. This market emerged in conjunction with the compliance market. However, intending to be a non-obligatory market, the VCM was initially low due to a lack of initiative by private entities. Many corporations have unveiled commitments to invest in forest carbon financing in recent years. Microsoft pledges to be carbon-negative by 2030, while Walmart and Amazon pledge carbon neutrality by 2040 (“A Green Growth Spurt | Ecosystem Marketplace”, 2021).

1.3 The VCM

The voluntary carbon market has been four years behind a functional carbon market for the last twenty years. The earliest records of this type of market were from the late eighties when the first investment from the private sector appeared in planting trees in Guatemala. In an

unregulated landscape, carbon credit certifiers started appearing, with the American Carbon Registry being the first private registry for voluntary offsets in the United States. Following Climate Action Reserve and Verra with the Verified Carbon Program (VCS) acting in the United States of America (USA) and Gold Standard in Europe, these institutions claim to certify projects, according to their methodologies, that have as objective the removal or avoidance of GHG emissions by compensating project developers with carbon credits.

The development of the VCM has been a gradual process compared to the compliance market, only constituting a small percentage of the global cut in GHG emissions. Nevertheless, it has gained traction recently with a new emerging global awareness of climate change. A growth spurt occurred from 2019 to 2021 when the market issued more than 300 million credits, and demand was at an all-time high. The following year, the reality of complex market mechanisms came to light, resulting in a slight fall in credit issuance. Nevertheless, market speculators believe that by 2030, the VCM will grow to over \$30 billion, 15 times more when compared with 2021 (McKinsey 2022).

1.4 Expected Contribution

The task in this field lab with Celfocus is to provide as much information as possible regarding the current state of the global carbon market. After a lengthy process of meetings, two Research Questions (RQ) were developed to address their objectives: i) How will the voluntary carbon market evolve, and how will policy and regulation affect the market adoption in Europe? ii) What are the certification costs of carbon projects, their trends and the investment opportunities that can be explored in South America and Africa? These topics will cover various issues such as market framework and functioning, technology in the VCM, policies and regulations, and investment opportunities. This research provides information to help Celfocus decide whether and how to build its carbon credit marketplace, while providing them with interesting investment opportunities in different regions.

1.5 Structure

This work project addresses the pressing issue of Climate Change and introduces the Voluntary Carbon Market. A thorough literature review examines the intricate structure of the market, the integration of blockchain technology, and policies and regulations governing the market, serving as a foundation for subsequent analyses. In addition, rigorous data analysis and comparative exploration of market trends, costs, and regional dynamics provide a comprehensive view of the market's evolving landscape. The Discussion section synthesises these components, fostering a nuanced understanding of the Voluntary Carbon Market. This thesis concludes by summarising key insights and implications.

2 Literature Review

2.1 VCM Structure

The compliance carbon markets work as a cap-and-trade system (Cap: Establishes a cap on the total amount of greenhouse gases that regulated industries can emit. Trade: Companies/Countries receive or buy emission allowances (permits), representing the right to emit a specific amount of greenhouse gases. These allowances can be traded among companies/countries.) where companies are obligated to participate if they do not meet the limit to their annual GHG emissions limit, which will be “capped” and lowered every year until 2050, when countries will reach the ambitious goal of ‘Net Zero’. An example of a compliance market is the European Union Emission Trading Scheme (EU ETS), regulated via the European Parliament and the Council of the European Union. Companies covered under the ETS must report their emissions annually, subject to verification processes to ensure accuracy.

Meanwhile, in voluntary markets, there is no governmental body ahead of them, nor is it necessary for companies to participate. It is a market for those who wish to help the environment while offsetting GHG emissions. As described by Kollmuss, Zink, and Polycarp, (2014), the voluntary markets do not require nor implement any particular policy mandates as the markets come from a voluntary ideology to help towards the climate change cause.

2.2 Stakeholders

The dynamic and voluntary nature of the carbon market involves a diverse array of stakeholders. Although numerous entities play a role, there are four key stakeholders, as detailed in Appendix 1. First, the project owner, who can be a singular or multiple proponents, is responsible for carrying out a project and has the legal right to do so. Project developers are usually companies that want to offset the emissions of their products or services.

Secondly, the registries set the standards and methodologies for GHG reduction or avoidance projects like Verra, Gold Standard, America Carbon Registry, and Climate Action Reserve by providing a registry system where all the projects and the carbon credits are stored.

Then, there is the Third-Party Verification Body (VVB). These are the companies that review, verify, and validate the projects based on the proposed methodology, according to the registry the project is registered with. To act, a VVB must register within the registry, or it will not be able to validate a project.

Lastly, there is the buyer. If project developers have a surplus of credits they want to sell, they will turn to the buyer, a singular or multiple party, who wishes to trade or offset emissions by using credits. The transaction of credits is either performed by a direct trade between developer and buyer or by an exchange like CTX (Carbon Trading Exchange).

Recently, more services, such as procurement, have emerged in the industry with companies like Abatable and South Pole standing out. These services gather financial resources for companies that want to offset their emissions by buying carbon credits or developing projects that generate such credits.

2.2.1 Certification Process

The certification of projects is a long-lasting bottleneck in project development, as seen in Appendix 2. To better visualise, the authors built a hypothetical example below:

Company X, headquartered in Portugal, wants to offset their product emissions. They need to gather data and information on their product emissions. After assessing their emissions, it was discovered that they emit 1 million tons of carbon dioxide annually. The following steps of company X are described in the figure below:

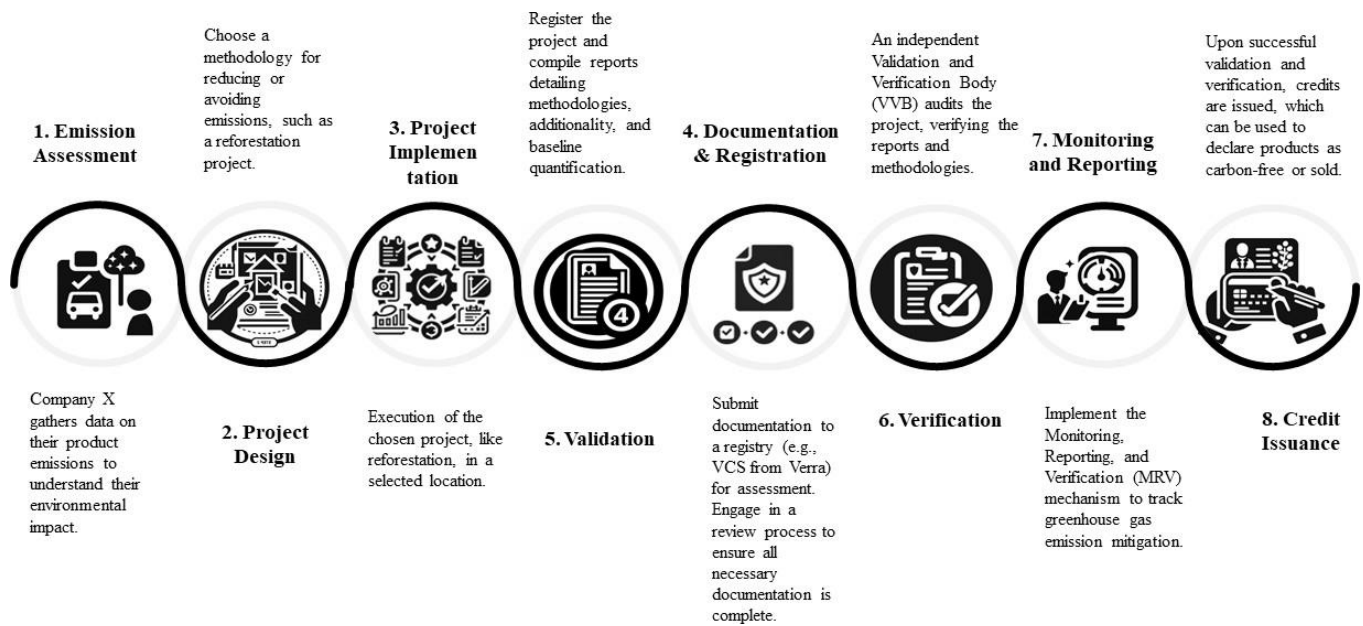


Fig. 1 – Carbon Project Certification Process

2.3 Carbon Emission Methodologies

To this end, carbon offset programs(registries) have been developing their technical methodologies following the United Nations (UN), which vary significantly according to the project scope, type, and location. These take time to develop and are usually compiled with specialists and institutional bodies with expertise in areas of interest such as Reforestation/Afforestation and Renewable Energy.

Carbon offset programs are developed per UN methodologies and tailored to specific project scopes, types, and locations. These methodologies involve experts in various fields like reforestation and renewable energy. Additionality is a fundamental principle in the VCM and is often misunderstood. Downey (2022) explained that a project is additional if it leads to emission reductions that would not occur naturally or through market forces alone. For example, a profitable solar project may be considered non-additional if it can operate without carbon credit sales. The UN Methodological Tool, Appendix 4 (UNFCCC/CCNUCC 2008), provides a framework for assessing additionality, including baseline scenarios and investment analysis.

Additionality plays a key role as Michaelowa, Hermwille, Obergasse, and Butzengeiger (2018) argue, ‘additionality is key to ensuring that no fictitious carbon units, that is, units that do not represent real emission reductions, compromise global carbon markets.’

Richars and Huebner (2012) define Permanence as the longevity and durability of carbon benefits. Carbon projects are deemed permanent if they store carbon for 100 years or more. However, physical disruptions can release stored carbon, negating benefits, an issue highlighted by Downey (2022).

Leakage refers to a potential unintended increase of GHG emissions in one location due to action taken to reduce emissions elsewhere. For example, if a carbon offset project protects a forest from logging but this leads to a necessity of logging elsewhere, then carbon offsets would not necessarily decrease emissions. In 2020, the European Commission published a new list of sectors and sub-sectors considered significantly riskier for carbon leakage and has policies to support investment in these areas (European Commission,2019). By incentivizing companies and projects to set up operations there, they aim to prevent leaking in those areas while helping more challenging industries transition to low-carbon practices.

Lastly, the Baseline estimation is critical to define when starting a new carbon project. The Baseline sets the ground comparison for calculating all other standards and the carbon units. For example, a baseline for tropical reforestation projects like Harris et al. (2012) developed shows an understanding of the current situation of the tropical forests, including therate of deforestation, area and density, making it possible to calculate more accurate emissionsavoided numbers. For context, his estimate is around 25 to 50% of the recently published estimates, showing that the baseline varies greatly depending on who does them, their methods,and their interests. Regardless, one undeniable truth persists: without accurate and dependable

estimates, any carbon market is at risk of failing to meet its objectives and promises, ultimately fostering mistrust.

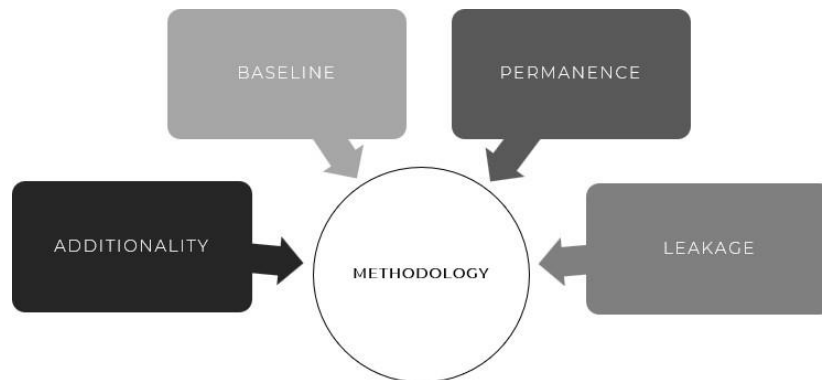


Fig. 2 – Components of Carbon Methodologies

2.4 Value-Chain

The development of projects is a costly process; the highest monetary cost occurs during a project implementation. This results in long-term investment, with very high upfront costs, which will only generate revenue after the certification process when selling the respective credit. The whole value chain can be seen in Appendix 5.

It is vital to note that project developers can receive revenue by creating methodologies. Certifiers of verified carbon units, such as Verra, give monetary support for developing these methodologies. Project developers who decide to do so will receive financial compensation at a variable rate based on credits issued, as shown in Appendix 6.

In a deeper view of what constitutes the costs of different projects, a study by Al Juaied and Whitmore (2009) reviewed different project types and their costs. Although every project generates carbon emissions, the price of each will mainly depend on its project scope. This makes sense, as an afforestation project will always have different costs from a technical point of view compared to a renewable energy one. Furthermore, projects within the same scope but of varied types - such as energy generation via solar panels or wind turbines - will exhibit vastly

different implementation costs. This discrepancy spans all scopes and types of projects, resulting in a substantial divergence in implementation cost.

3 Blockchain on the VCM

3.1 Blockchain

Blockchain is a technology regarded by many as a transformative and revolutionary innovation. According to Conte de Leon et al. (2017), a blockchain can be defined as a “digital information recording method capable of recording data using a logbook approach and with the following essential characteristics: i) Ordered; ii) Incremental; iii) Sound (cryptographically verifiable up to a given block) and IV) Digital”.

There are currently three types of blockchain in use, as noted by Vokerla et al. (2019). Private blockchain, where the access is tightly controlled, and the “general” public can read but not alter any information. Consortium Blockchains, a semi-decentralized blockchain, are still tightly controlled by a larger group of entities. Finally, Public Blockchains, where everyone can join as a node and participate in the network if they have an internet connection and a computer device that can run the blockchain. This is where true decentralisation exists. Being a peer-to-

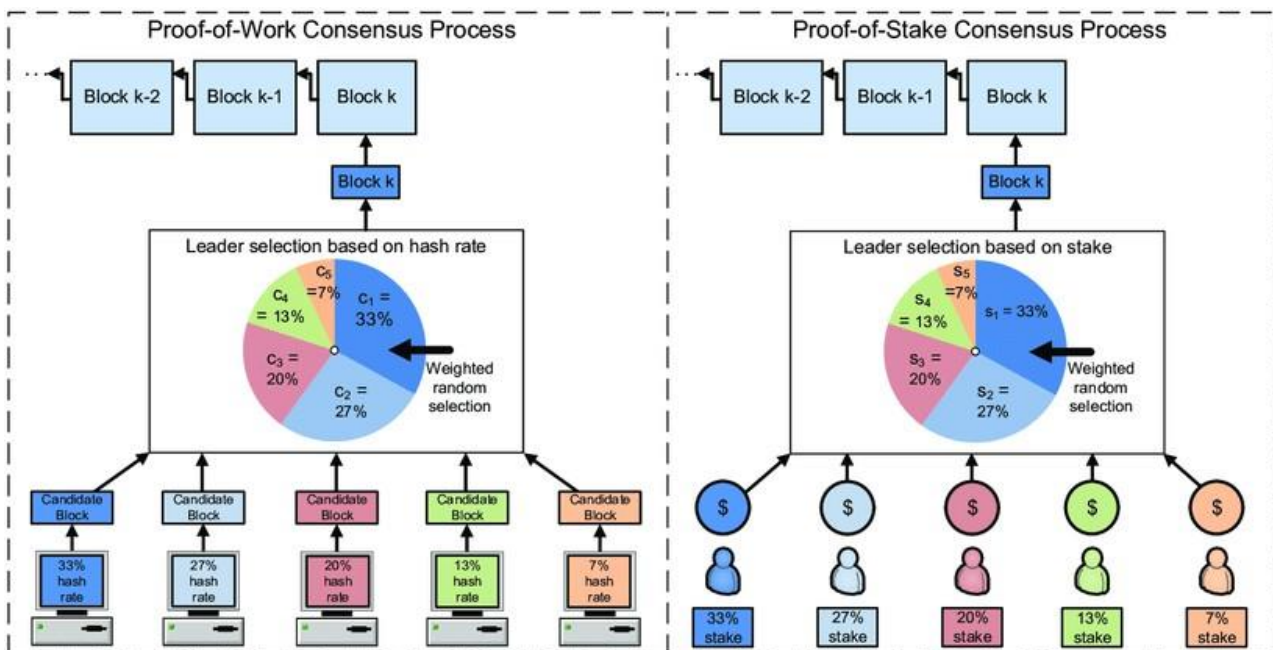


Fig. 3 – PoW and PoS Consensus Mechanisms Comparison.

Source: Proof-of-Stake Consensus Mechanisms for Future Blockchain Networks: Fundamentals, Applications and Opportunities”

peer network where one or more nodes share resources without needing a centralised system, blockchain will facilitate direct communication between project developers and buyers. Buyers can search for projects and automatically know the credits that align with their preferences. Regardless of the network type, every blockchain comprises a distributed ledger technology (DLT) that maintains a continuously growing list of ordered records called blocks. As shown in Appendix 7, blocks contain their unique hash (digital fingerprint), the timestamp of a recent batch of validated transactions, and the previous block's hash. For these blocks to be created and published in the network, there needs to be a consensus mechanism that can manage the network's security.

This mechanism can be described as a “set of certain mathematical rules and functions that allow it to reach an agreement between all participants (nodes) and ensure the operability of the network” (Vilkov and Tian, 2023). Different Blockchains have implemented different consensus mechanisms, but two have been extremely popular: Proof of work (PoW) and Proof of Stake (PoS). Figure 3 sums up the differences in both processes.

However, when considering a specific blockchain application within the carbon market, utilising Proof of Work (PoW) becomes unfeasible and potentially counterproductive. PoW necessitates an exorbitant number of energy-intensive computations to solve the mathematical equations required for hash discovery, contributing to Bitcoin mining's electricity consumption surpassing that of numerous developed nations (Corbet, Lucey, and Yarovaya, 2021). Therefore, employing a PoW-based blockchain solution to assist the carbon market could exacerbate climate change issues. Instead, a Proof of Stake (PoS) solution offers enhanced energy efficiency. Ethereum, a cryptocurrency that has transitioned its mechanism from PoW to PoS, has achieved a remarkable 99.9% reduction in energy consumption, rendering it a reasonable and applicable choice for the carbon market (Paola, 2022).

Another critical property of blockchain, and why its use could be so valuable for the VCM, is the immutability of its records. As Hofmann et al. (2017) put it, “recorded data cannot be manipulated or modified after being accepted by the blockchain network”. This would provide much more confidence in the quality and legitimacy of carbon credits, backed by actual data on the blockchain that cannot be altered. Wrongdoing like the ones discussed in section 4 could be more readily identified and prevented using blockchain technology.

Another key problem highlighted by Tabitha Whiting (2023) is when the trading of credits occurs between countries, with both the seller and the buyer counting them towards their own emissions reduction goals. Double counting “can result from double issuance, double claiming, and double use” (Marchant, Cooper, and Gough-Stone, 2022). Double counting is a big problem because the real impact is half what is accounted for. By using Blockchain, levels of traceability and monitoring increase such that this problem might actually become a non-issue, as credits are automatically retired once purchased and those transactions get stored on its ledger. (Marchant, Cooper, and Gough-Stone, 2022).

3.2 Current Implementations

Blockchain-based solutions in the VCM landscape have started to appear in recent years, with two exciting projects worth the emphasis.

3.2.1 KlimaDAO

KlimaDAO is an example of a decentralised autonomous organisation (DAO) that fulfils the need for a global, borderless entity that coordinates agency relationships, enforces expectations, and limits liabilities through smart contracts. These digital organisations can be used for various purposes, including exchanging digital assets, speculating, facilitating cross-border money transfers, and time stamping. DAOs also have potential applications in financial transactions, secure voting, autonomous organisations, company management, freedom of

speech networks, online games, crowdfunding, and speculation, among many other possibilities that cannot be anticipated (Kaal 2021)

KlimaDAO is a digital reserve currency backed by carbon credits. Much like gold once gave value to the US dollar, the \$Klima token is backed by natural assets, in this case, BCT (Base Carbon Ton) and MC02 (Moss Carbon Credit), where one BCT or MC02 equates to a ton of sequestered carbon. Specifically, BCT is a token created by a crypto project named Toucan Protocol that takes carbon off-chain and brings it to the blockchain. Figure 4 illustrates this interaction between BCT, Klima and a crypto user. If a registry like Verra approves the emission of credits for a specific project, Toucan puts those credits on the blockchain, which can now be tracked and re-sold. MC02 has a similar use case, but it only operates with projects from the Brazilian Amazon.

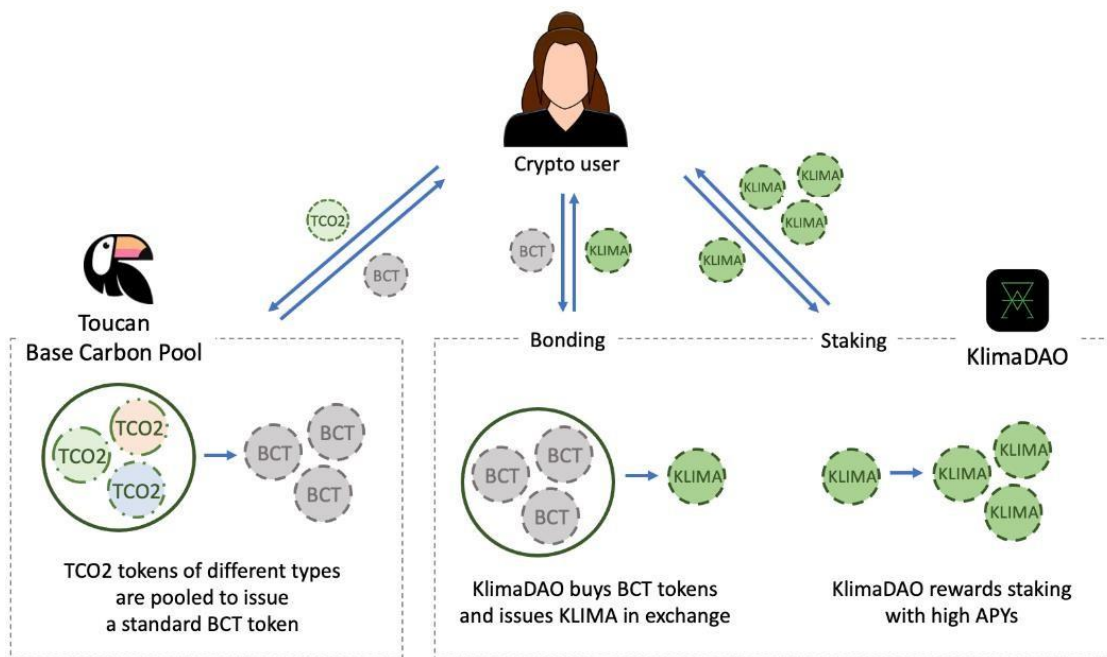


Fig. 4 – Example of an interaction between Toucan, KlimaDao and crypto user.

Source:(Gutierrez 2021)

For now, KlimaDAO and the Toucan Protocol have a market cap of over \$10 million, a small portion of the total cryptocurrency market cap today at around 1.4 trillion.

3.2.2 Nori

Nori is a carbon removal marketplace with innovative blockchain technology based on tokenising carbon offsets as Non-Fungible Tokens (NFTs). They have partnered with many farmers to create regenerative agriculture projects that store carbon in the soil. What makes Nori unique is the Nori Carbon Removal Certificate that accompanies each purchase, providing the exact amount of carbon removal credits and their serial number, recorded on the blockchain (Appendix 8). By purchasing with Nori, one is also buying credits from a project whose compromise is to sequester carbon for at least ten years, as assured by Nori. After creating projects, an independent third-party estimates carbon removals and verifies everything every three years. Moreover, every detail about the project is stored in their blockchain and is publicly accessible through their website. Credits can be bought, and customers can select how many they want. The certification is then issued and can be used to prove ownership of the credits and prevent double counting, as each certificate is unique and delivered to only one individual.

Nori's solution fills the gap of having a blockchain technology solution backing their services, but also an easy-to-use friendly marketplace perfect to match buyers and sellers around the globe. It is worth noting that no one needs to transact in cryptocurrencies; all can be done through dollars, and credits can be bought with a few clicks, like a standard online purchase.

Nori and KlimaDao were the first to bring blockchain to registering, selling, and retiring credits. Nonetheless, the role of blockchain in this market is still completing its early steps, and one stage has yet to be disrupted.

3.3 Future Implementations

Currently, MRV practices are all but standardised; every register has its methods and programs. Different projects have different methodologies, and this lack of standardisation

leads to problems in “inefficiency, credibility, utility, and cohesiveness of MRV processes and results” (Bauman 2020).

3.3.1 Digital MRV

One idea to combat these issues is the introduction of a digital MRV, where IoT devices can do all the measurements and verify emission reductions regularly without any human interference, avoiding human errors. Figure 5 represents a general digital MRV process.

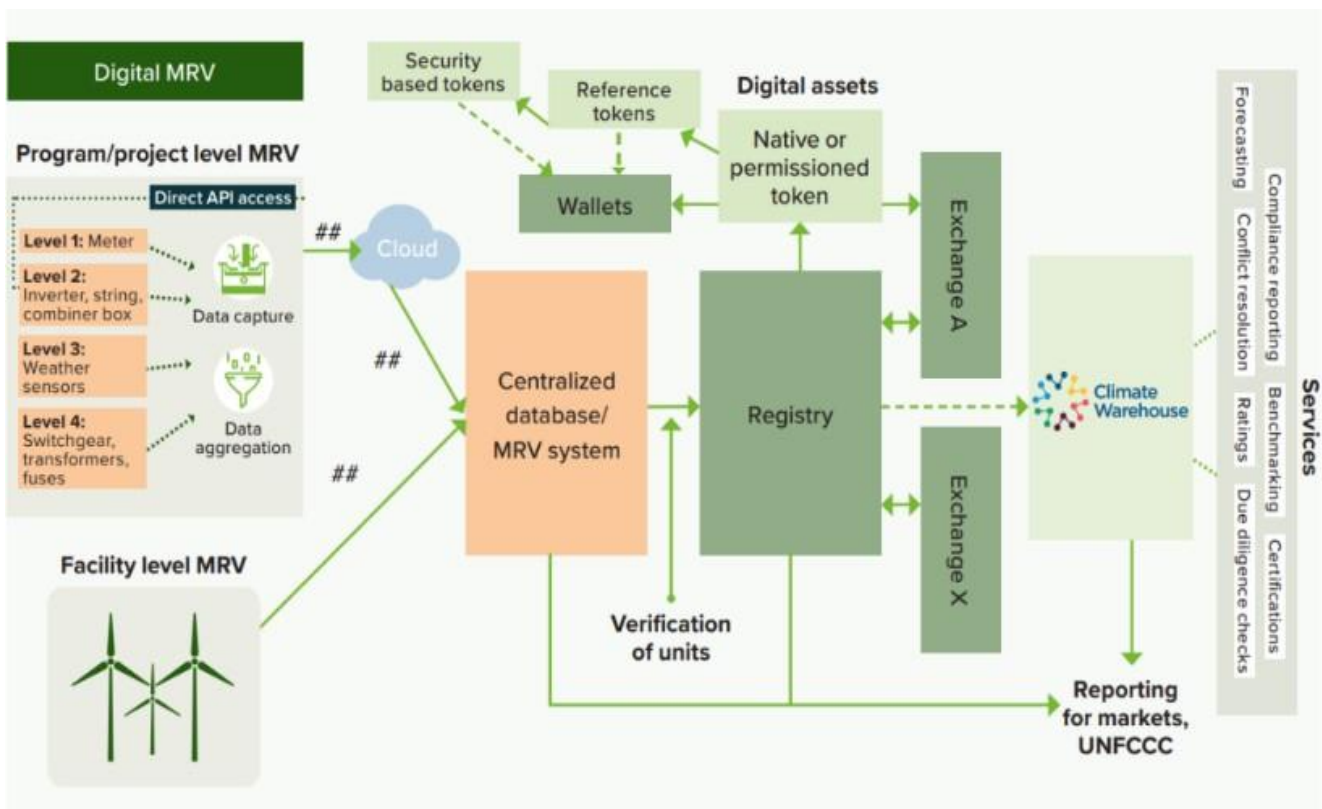


Fig. 5 – End-to-end digitalization of carbon market infrastructure using Digital MRV.

Source: World Bank. 2022. Digital Monitoring, Reporting, and Verification Systems and Their Application in Future Carbon Markets.

A universally adopted Digital MRV framework requires consistency and adaptability to ensure its applicability across different contexts. This standardisation will also expand access to the carbon market as regulatory frameworks become more comprehensive and transparent, ensuring a level playing field for all participants. Lastly, Digital MRV has the potential to act

as a catalyst, driving corporate supply chains towards increased “transparency and accuracy on climate and sustainability impacts” (Climate Ledger Initiative, 2018).

Creating a blockchain solution will eventually lead to more efficiency, transparency and traceability in the carbon market, decrease existing barriers and increase data quality (Fuessler et al. 2018).

4 Policies & Regulations:

Throughout this research, one can see how VCM has the potential to help mitigate climate change. Nonetheless, according to Battocletti, Enriques, and Romano (2023), there is “evidence that the VCM has not always delivered on its promises.” As a result, tighter regulation has long been asked for. This section explores policies and regulations alongside some of the main controversies that have shaken this market’s confidence.

4.1 VCM Controversies

No industry or company is usually exempt from controversy or another throughout their lifespan, but the Carbon Credit market is very different. At the beginning of 2023, a Guardian report on a handful of rainforest conservation projects raised significant doubts on whether these projects are practical. According to their research, only a handful of Verra’s rainforest projects showed evidence of deforestation reductions, with further analysis indicating that 94% of the credits had no benefit to the climate (Greenfield 2022). The analysis targets a specific type of credit called REED+, which is short for Reduced Emissions from Deforestations and Forest Degradation. The “+” mark refers to additional forest-related activities. One example of a REED+ credit is keeping and protecting a forest that would otherwise be cut down for business purposes. Landowners get the revenue from credits and, in return, delay cutting the forest for wood or any other profitable activity. While many claim REED+ type of credits are a failed scheme (“REDD+: A Scheme Rotten at the Core | World Rainforest Movement” 2019), Barbara Haya, director of the Berkeley Carbon Trading Project, believes “rainforest protection credits are the most common type on the market at the moment”, adding that “These problems are not just limited to this credit type. These problems exist with nearly every kind of credit.” (Greenfield 2023a). It is worth noting that Disney, Shell and Gucci have all bought rainforest credits from Verra, leading some of them to label their products as “carbon neutral”. This investigation resulted in a lot of distress and uncertainty. Verra’s CEO left the company

following the news after more than 15 years of running the business, despite no wrongdoing ever being confessed.

In another example, an article by the New Yorker in 2023, entitled “Great Cash-for-Carbon Hustle” (Heidi Blake 2023), highlights a scandal with a Project Developer called the South Pole in a project named Kariba. This project faced allegations of financial irregularities, mismanagement of funds, and inflated claims regarding reducing carbon emissions, with some even saying the project “actually resulted in more carbon emissions”. An audit took place after the project was completed ten years later and found that only fifteen million of the forty-two million carbon credits had been backed by avoided emissions. In response, South Pole always insisted that the Kariba credits sold would ultimately be backed by actual emissions in the future. However, people visiting the project site found nothing but abandoned vegetable gardens.

Projects producing credits with an inflated rate and low reliability are uncommon, diminishing trust in the system and the offsets companies buy. This helps explain why the demand for this market has collapsed for the first time in years, as Sarah Mcfarlane and Susanna Twidale (2023) noted.

4.2 Legislation in the VCM

The Paris Agreement was crucial for accelerating the VCM as we know it today, with Article 6 having several subsections outlining most of the structure. Article 6 acknowledged that countries could pursue voluntary cooperation in implementing their nationally determined contributions to allow for higher mitigation ambition and promote sustainable development. Subsection 6.2 describes the process that allows countries to trade emission reductions and removals with one another through bilateral or multilateral agreements. These traded credits are called Internationally Transferred Mitigation Outcomes (ITMOs). Either country can buy them to meet their NDCs or private entities to meet voluntary goals to reach net zero. An example

can be seen in Appendix 9. Another important subsection is Article 6.4, the successor of the Clean Development Mechanism (CDM), the first international carbon market developed under the Kyoto Protocol in 1997. This article establishes a voluntary carbon market: "A company in one country can reduce emissions in that country and have those reductions credited to sell them to another country. That second company may use them to comply with its emission reduction obligations or to help it meet net zero." (Article 6.4 Mechanism | United Nations). Here, carbon credits are sorted into three categories, depending on whether they are UN accredited and have undergone adjustments. Credits resulting from these initiatives are called mitigation contributions or unauthorised credits. Appendix 10 lays out the structure of the subsection, explaining which type of credits may or may not be authorised to count towards NDC's contributions.

Following the controversies discussed in the former section, two big questions remain unanswered in Article 6. One is the decision to include or exclude REED+ credits inside Article 6.4, as there is no official definition of removals, reductions, or avoidance. The second consideration is whether Article 6.4 will allow independent registries such as Verra or Gold Standard to participate in this mechanism and supply credits.

4.3 Important Legislations in other Markets

4.3.1 Markets in Crypto-Assets

MiCA, short for "Markets in Crypto-Assets," is a proposed regulatory framework within the European Union (EU) designed to regulate various crypto-assets and related services. This initiative is part of the EU's broader Digital Finance Package. MiCA's goal is to ensure legal clarity, consumer protection, and financial stability while promoting innovation and uniformity in terms of regulation. MiCA establishes the rules for the issuance, admission of trading and operation of crypto assets.

The draft defines crypto assets as "a digital representation of value or rights that may be transferred and stored electronically, using distributed ledger technology or similar technology" (C. Maia and Vieira dos Santos 2021). Among many other features, MiCA stands out for establishing a single licensing regime for crypto issuers, setting requirements, promoting legal certainty, introducing a taxonomy for crypto assets, and categorising them into different types. Appendix 11 lays the structure of that taxonomy, and (C. Maia and Vieira dos Santos 2021) go much deeper into analysing MiCA's framework throughout their research.

In short, MiCA divides crypto assets into three distinct categories. The first one is utility tokens, which refer to any unique crypto project in terms of value and include governance tokens that allow users to vote or participate in a specific crypto ecosystem. The second class are asset-references tokens (ART). These are tokens based on an underlying asset, like a commodity or real estate, and pegged to their value. The final class is referred to as e-money, like centralised stablecoins, but does not apply to any stablecoins issued by the IMF. The bill does not apply to blockchains or coins like Bitcoin, Ethereum, and Cardano. When it comes to NFTs, they now need to meet standards by registering with the authorities and presenting a whitepaper to avoid fraud and better schemes.

How exactly does MiCA relate to the carbon credit market? How can this influence it? Blockchain can help address some of VCM's issues, as discussed above. It can enhance trust in entities and projects by using decentralised structures that care for all procedures or improve the digital MRV, helping with data measurement and processing transparency. Blockchain can provide the necessary infrastructure to combat climate change at speed and scale ('Blockchain for Scaling Climate Action | World Economic Forum' 2023).

Despite MiCA's framework primarily protecting the euro against the rise of stablecoins, it also promotes the use of blockchain under a supervised look. This will allow for the development of projects under clear regulatory circumstances throughout Europe. This

encourages cross-border operations, international cooperation, and support from governments and banks to support and finance blockchain initiatives, something that did not happen before. In addition, Europe has had the most significant trading volume of traded carbon for more than five years Qin and Coker (2023). All these factors combined will encourage more players into space and equip them with better funding to succeed in bringing value to the carbon markets.

4.3.2 Corporate Sustainability Reporting Directive

The Corporate Sustainability Reporting Directive (CSRD) is a significant piece of legislation implemented by the European Union. It mandates all large companies and lists Small and Medium Enterprises (SMEs) to publish regular reports on their environmental and social impact activities. This directive is designed to help investors, consumers, policymakers, and other stakeholders evaluate these companies' non-financial performance.

CSRD plays a crucial role in the Voluntary Carbon Market. The CSRD requires companies to report their greenhouse gas emissions, a key aspect of the VCM. By making this information publicly available, the CSRD enhances the transparency and accountability of the VCM. This allows stakeholders to assess a company's carbon footprint and the effectiveness of its carbon-offsetting efforts. This can influence investment decisions and drive companies to reduce emissions and participate more actively in VCM. (Whittingham et al. 2023).

5 Research Methodology

5.1 Research context

Celfocus gave a set of objectives to address the task at hand, four main areas of study were found, and the research questions were made. To face the questions, a mixed-method analysis was undertaken, enabling a broader understanding of the research Malina, Nørreklit, and Selto (2011).

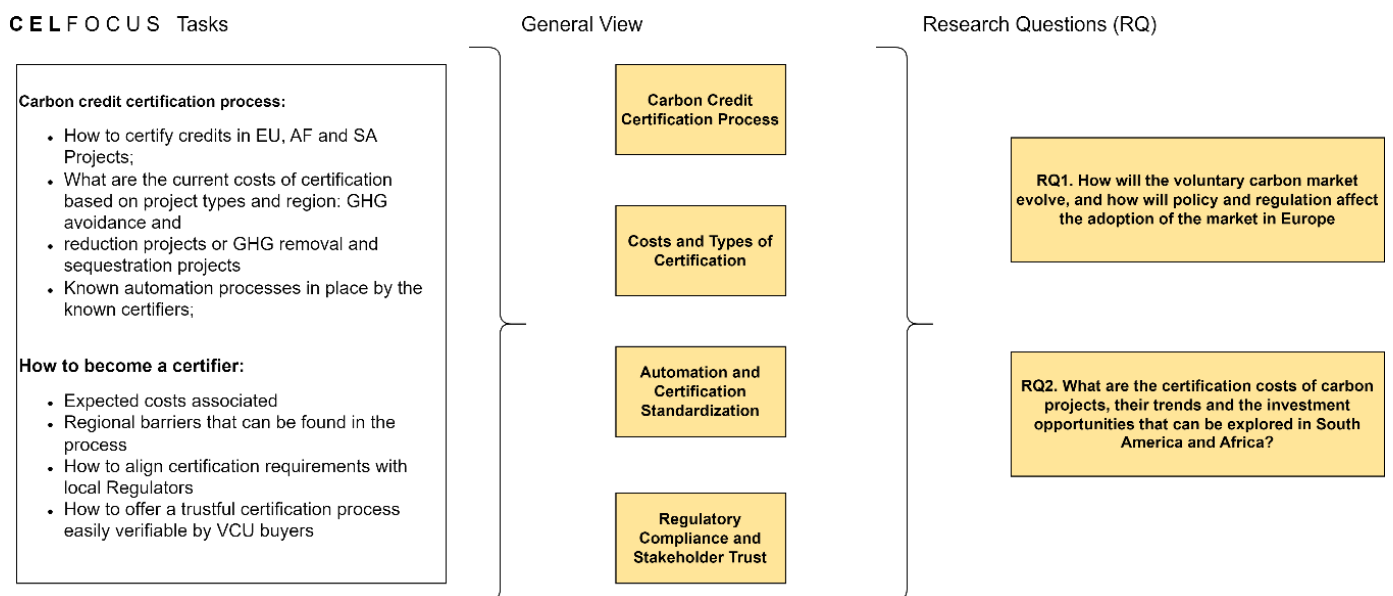


Fig. 6 – Research Question Formulation Process with Celfocus

The methodologies in this section are divided into qualitative and quantitative, and each part is structured in three steps: i) Data Collection and Processing, ii) Methods, and iii) Findings. Refining the Research Questions with Celfocus was an extensive process (Figure 6). It led to the identification of two key research questions:

5.2 Qualitative

The qualitative research of this paper reaches for the utmost insightful understanding through the use of interviews, as it is regarded appropriate when the researcher or investigator explores a novel domain of study or aims to examine and formulate theories on significant issues Jamshed (2014).

5.2.1 Data Collection and Processing

Voluntary carbon market stakeholders represent a great source of accurate raw information regarding understanding the market environment. The authors contacted representatives from registries about the certification process and legal experts in touch with European regulation on this market to get a more comprehensive understanding of its policies.

This process was carried out through snowball sampling Goodman (1961). This resulted in six semi-structured interviews, as represented in Appendix 12. All the interviews were conducted through video calls, using web applications such as Microsoft Teams, Zoom and Google Meets, allowing for recording and easier access to automatic transcripts. Participants were informed of the option of anonymity to ensure responses would be anonymised and used solely for research purposes. Consent was obtained before the recording, detailing the purpose of the research, the voluntary nature of participation, and assurance of confidentiality.

The authors prepared a script to guide these interviews to provide a foundational structure for the discussions. This script is available in Appendix 13 and served as a reference point during the interviews. These were designed to explore the diverse impacts of each participant on their interactions within the voluntary carbon market. Slight deviations occurred during this, allowing for a natural flow of conversation and an in-depth exploration of participants' perspectives.

5.2.2 Data Analysis Methods

Interview transcripts were meticulously examined using conventional (inductive) content analysis, as presented in Appendix 14, as Hsieh and Shannon (2005) outlined. Despite the structured script, interviews naturally meandered, leading to responses that did not always fit into predetermined categories. The authors used the process of noticing, collecting, and thinking to address this issue, inspired by Seidel's approach.

The inductive content analysis on transcripts described by Delve and Limpacher (2023) enables a deep understanding of the data. While segregating information into themes helps identify patterns and categories altogether, it has some issues, as it can be challenging to balance immersion in the data and focus on the research question. The development of codes demonstrates a detailed focus on the content. As referred before, there was a natural flow to the interviews to assist in the inductive conduct, noticing, collecting, and thinking methods used. Noticing facilitated the identification and coding of interview segments, collecting was instrumental in organising these coded insights, and thinking involved analytical examination of the segmented and organised data. The recursive nature of noticing allowed for additional questions during the interviews, enriching the depth of discussion.

5.2.3 Qualitative Results

Quality of credits was a hot topic amongst interviewees, who expressed significant remarks. Mentioning recent articles from The Guardian, project developers expressed uncertainty about the methodologies used by registries. To address this issue, project developers mentioned that a second layer of a project evaluation can bring calm to the market. Procurement services have advertised "high-quality credits" with additional measures in the standard process, including stringent criteria for removing project types, emphasising additionality, permanence, and leakage. Quality concerns significantly impact the credibility, price and effectiveness of the voluntary carbon market, potentially eroding the trust that both investors and the public have in carbon credit initiatives. Nevertheless, registries stay firm on their standards, as it was said to be an error and learning mechanism. Overall, research has revealed a need for improved quality standards, and interviewees have suggested adopting more rigorous certification processes and transparency measures to address this issue.

Transparency, the lack of transparency in project development, was highlighted in every interview. All acknowledged the significant implications for public perception, investor

confidence, and the functionality of the voluntary carbon market. Despite the availability of specific information on registries' websites, interviewees emphasised the inefficiency of platforms providing up-to-date and comprehensive details, including images and reports on projects under development. Establishing a public platform with real-time project updates, detailed reports, and visual documentation is critical to fostering trust among stakeholders, attracting investors, and ensuring the proper functioning of a future marketplace. This may result in a more local supply as information is closer to the supplier, cutting short investment incentives for less developed countries.

Legal barriers are a significant challenge to the development of carbon credit projects, particularly in the context of European Union regulations, according to both project developers and legal experts. These barriers relate to national laws, project size, methodology application, and compliance with varying national policies. The impending impact of EU regulations on project development has raised concerns about credit quality assurance. However, a registry representative has revealed that certification bodies are committed to helping governments transition to a greener future and are available to assist with this process. To address these legal barriers, a collaborative effort is necessary to adapt certification frameworks and ensure they are aligned with evolving regulatory landscapes, promoting a smoother project development process.

Few interviewees provided sources for datasets or information about carbon pricing. When provided, the authors encountered paywalls to get carbon credit prices. Trading of credits is conducted in a non-public sight inside registries or by procurement services. Carbon trading is mainly done on a demand basis from companies that advertise products as sustainable and carbon-free and pledge to go net zero until 2050. A higher demand searches for projects already producing credits, disregarding projects in the early stages of development where financing is

most needed. Credits are bought with the vision of a company's footprint, usually for the next 10-15 years.

A Blockchain-based marketplace spiked interest among interviewees. Most were not fully knowledgeable about how the market could work and if there was already an implemented solution. Even so, most appealed to the solution based on their conception of the nature of blockchain. A remark made by a project developer went back on the idea, stating that buyers of carbon credits and companies funding projects can and happen to decide to be anonymous. Despite that, it was said to be a smart solution regarding transparency. As it is currently one of the most pressing issues, besides traceability and double counting, ledger technology could solve it. A spokesperson for a registry has indicated that it is possible that governments may consolidate registries in the future, utilising either blockchain technology or a more advanced system, in order to establish a global standard.

Overall, interviewees highlighted that the market objectives passed through the need to achieve the net-neutrality goals brought from the Paris Agreement, picking up the individual objectives of each country. The VCM is a powerful tool to mitigate climate change and bring development to third-world countries with sustainable investment, complying with the Sustainability Development Goals (SDG). Nonetheless, there is a consensus among interviewees that the market is flawed and filled with a lack of credibility, regulation, and harmful practices.

5.3 A Quantitative Inquiry into Market Trends, Costs, and Regional Dynamics

(Quantitative)

Interviews served as an essential method to gather data. However, with the vast market landscape, authors found it best to perform secondary data analysis (Tripathy, 2013) since it can enclose data from a wide range of aspects needed to meet the requirements given by Celfocus. Figure 12 represents the contribution of each step taken to answer the research

question. The section is divided into data collection, data pre-processing and analysis. These sub-sections have information on the data gathered, curated, and analysed and its respective methodologies.

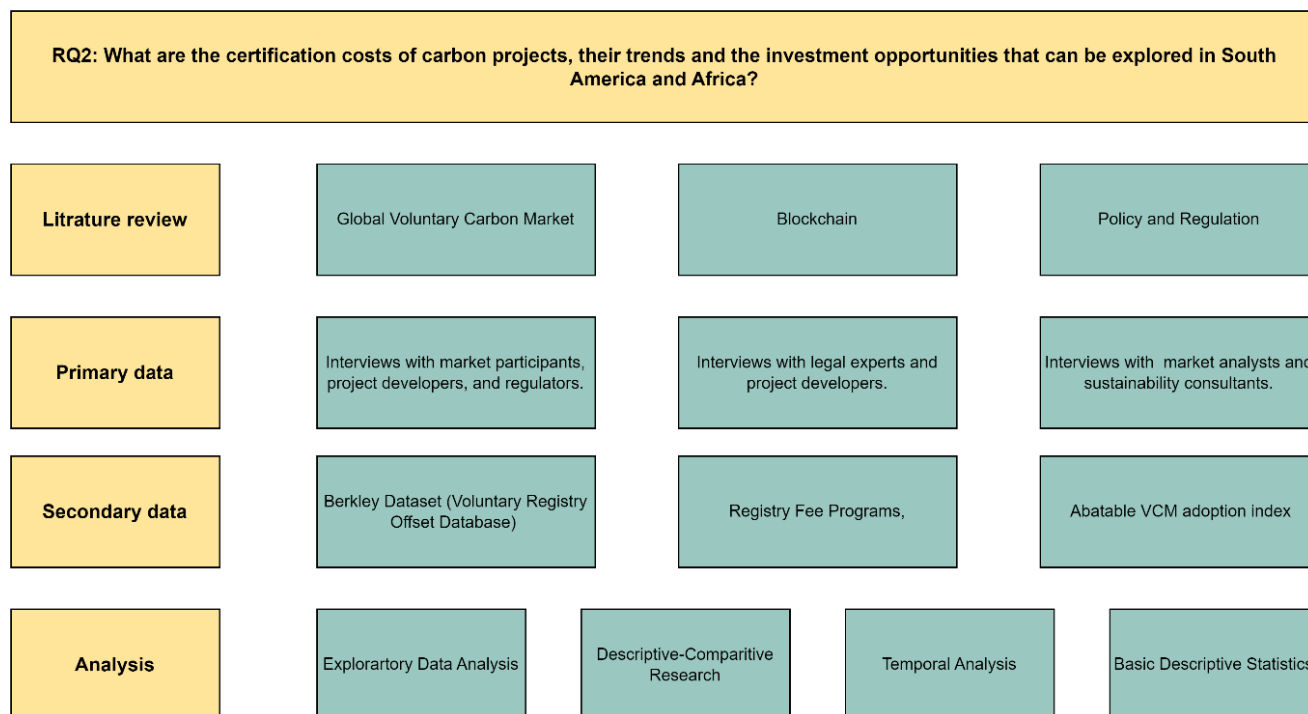


Fig. 12 – Second Research Question

5.3.1 Data Collection

The primary data source used is a database from the Berkeley Carbon Trading Project, a project focused on studying the effectiveness of carbon trading. The database contains all carbon offset projects listed globally from 1996 until May 10th, 2023, by the four leading voluntary offset project registries. Those registries are the American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard (GOLD), and Verra (VCS). The dataset is publicly available online in Ivy S. So, Barbara K. Haya, and Micah Elias. (2023, May). Voluntary Registry Offsets Database, Berkeley Carbon Trading Project, University of California, Berkeley.

For certification costs, every registry website was searched to find their fee structure. All the mentioned registries usually update their fee policy on an annual basis. The most recent fee structure available for each registry was used.

Finally, an index evaluating countries based on three factors was taken from Abatable, a platform connecting project developers and credit buyers. This Index was designed to provide capital allocation risk in the VCM. The three factors are: i) *Global carbon market readiness*, that looks at the jurisdiction's experience in hosting VCM projects and its readiness to manage its engagement with Article 6 of the Paris Agreement; ii) *Investment landscape*, providing insights into the national political and economic context as a measure of the risks for foreign investors; iii) *Climate, nature and people opportunity*, quantifying the potential impact of the role the VCM can play in closing the financing gap to reduce emissions, conserve critical ecosystems and improve livelihoods (Abatable, 2022).

5.3.2 Data Pre-Processing

Data pre-processing is needed or may cause problems and make data analysis unnecessarily complicated, as described by Famili et al. (1997). For this step, the programming language Python was used. It is an excellent data science tool for data manipulation, analysis and visualisation (Rayhan and Gross, 2023).

For Abatable data, web scrapping techniques were used to gather data into scripts and codes and only Countries that were also present in the Berkeley Data were included. On the Berkeley dataset, 21 irrelevant variables to the study were identified, in addition to 20,000 missing values that were curated via removal or filled in using neutral values. To avoid sampling bias, projects that had been registered but had no credits yet issued were not considered. For certification costs, it is essential to note that methodologies review fees for GOLD and CAR could only be obtained by direct contact. Therefore, these values were assumed to be equal to the average of the other samples. Moreover, VVB fees were only available in GOLD, so they were assumed to be the same in other registries, as they work with similar partners. All of these values are identified with “*” in Table 1.

The final results were represented in the form of Jupiter Notebooks (<https://gitlab.com/bmanarte/voluntary-crabon-market-analytics>)

5.3.3 Data Analysis Methods

The research began with an exploratory data analysis of the Berkeley Dataset. First, it is essential to distinguish two critical variables standard in the analysis: Project Scope and Project Type. While type refers to the specific type of the project, like “wind” or “solar”, a scope aggregates several types of projects. In this example, wind and solar-type projects would be under a “renewable energy” scope. To begin with, data visualisation techniques were used (Srivastava 2023) to extract information about project lengths for different project types and establish trends regarding credit issuance for different project scopes.

Next, registry fee programs were imported to Python scripts for subsequent analysis of certification costs. Fees are separated in fixed fees (usually annually pre-determined fees) and variable fees (fees dependent on the issuance of credits, like a tax). Not all available fees were used to make the analysis. Instead, only fees guaranteed to be paid by a project developer were considered. Fees like cancellation fees, transfer fees, or fees for wanting to submit specific protocols or methodologies were not included, as they are very case-specific. Nonetheless, they represent a tiny percentage of the total fees, having a minimal impact on the results.

These fees were then calculated for every project. However, results were skewed because some registries had issued more credits than others. Therefore, to accurately measure certification costs, they needed to be standardised to the number of credits each registry had issued. This was done by dividing any project costs by the number of total credits issued, effectively getting a unitary certification cost (a certification cost per credit issued or, similarly, per ton of GHG avoided/removed). The same method was used to calculate the unitary cost per project scope. It is essential to highlight that instead of using the average of the credits, the

median was used to obtain a better proxy for central tendency, given that some projects had very extreme values of issued credits that skewed the average (Manikandan 2011).

Afterwards, the average time between the first year of the project and the last year it issued credits was calculated for different scopes. This will give insight into how long a project usually runs, making their fixed fees more predictable.

Descriptive comparative research described how costs varied between registries and scopes (Miri, Shahrokh 2019). Different project timelines were also compared for different scopes.

Next, a temporal analysis that investigates the trend of new projects registered each year for 26 years, was conducted (“5.8 Temporal Analysis” 2023.).

Lastly, descriptive statistics was used following Yellapu (2018) to summarise Abatable’s index data by identifying patterns and outliers that exhibit exceptional positive or negative characteristics in our dataset.

5.3.4 Research Findings

Research began with an overall analysis of fixed and variable certification fees for the different registries and the regions of interest, South America and Africa. Table 1 shows the primary fees collected from the four leading registries and used in the Python Scripts, already segmented into fixed and variable fees.

Overall, all registries have similar fee structures. Gold Standard stands out for their aggressive strategy on variable fees, imposing a “tax” on issued credits of 30%. Nonetheless, they cut costs in Project Registration, and there is no account opening fee, making it easier for a project with little to no money to start developing, for example.

	Fees (in \$)	Verra	Gold Standard	ACR	CAR
Fixed Fees	Account Opening Fee	500	0	500	500
	Account Maintenance Fee (annual)	500	1000	500	500
	VVB review fee (3y)	2500*	2500	2500*	2500*
	VVB renewal fee (3y)	1500*	1500	1500*	1500*
	VVB approval fee (annual)	1500*	1500	1500*	1500*
	New Methodologies review fees	15000	13000*	12000	13000*
Variable Fees	Issuance Fees (per credit in cents)	0.2	0.3	0.15	0.19

Table 1 – Registry Fees

Interestingly, one can also analyse how fees vary from project scope in the South America and African regions (Figure 13, 14). In South America, issuance and variable fees change a lot according to different projects, while in Africa, issuance fees dominate. This analysis might be helpful for Celfocus when deciding which projects to accept in their marketplace and from which regions, according to their business model.

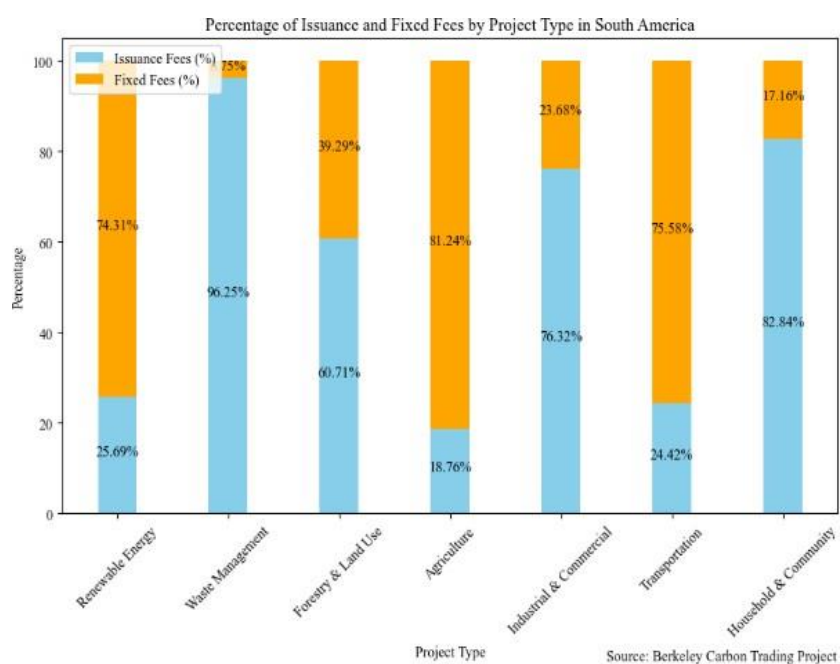


Fig. 13 – Issuance and fixed fees per project scope in South America

In general, it can be concluded that African projects issue a more reasonable amounts of credits, paying higher issuance fees because of it.

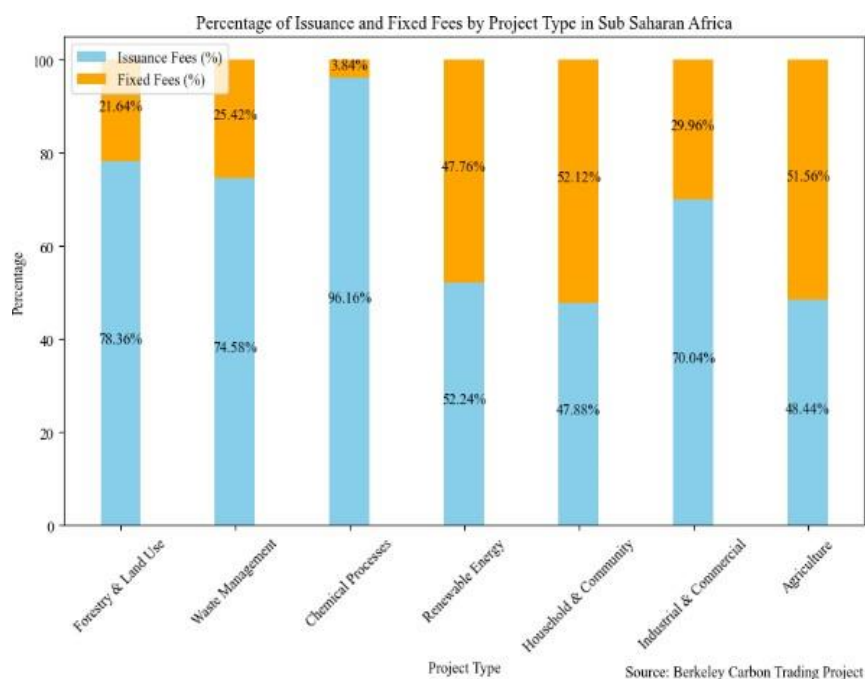


Fig. 14 – Issuance and fixed fees per project scope in Africa

Regarding registries, Figure 15 sums up how registries made their money from fees in the first 1 million credits sold. Table 2 displays the median cost per credit by certifying a project with those registries.

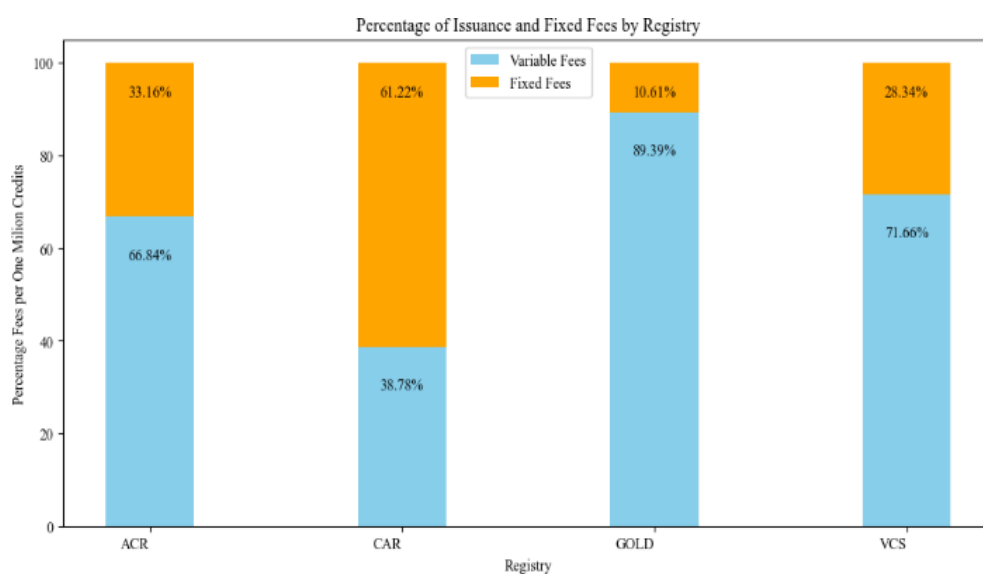


Fig. 15 – Issuance and fixed fees per registry

Voluntary Registry	Median Cost per Credit
ACR	0.737
CAR	0.571
GOLD	0.829
VCS	0.315

Table. 2 – Median unitary cost per credit

It is important to note that while GOLD emerged as the most expensive registry per credit, probably because of the type of projects it partakes in, its fee revenue came primarily from issuing credits, while CAR was more dependent on fixed fees. These are essential considerations when choosing a registry to certify projects, depending on how many years the project is expected to go on for and how many credits it expects to issue.

The exploratory data analysis on the Berkeley Dataset continued, with the findings of the number of projects per scope shown in Figure 16.

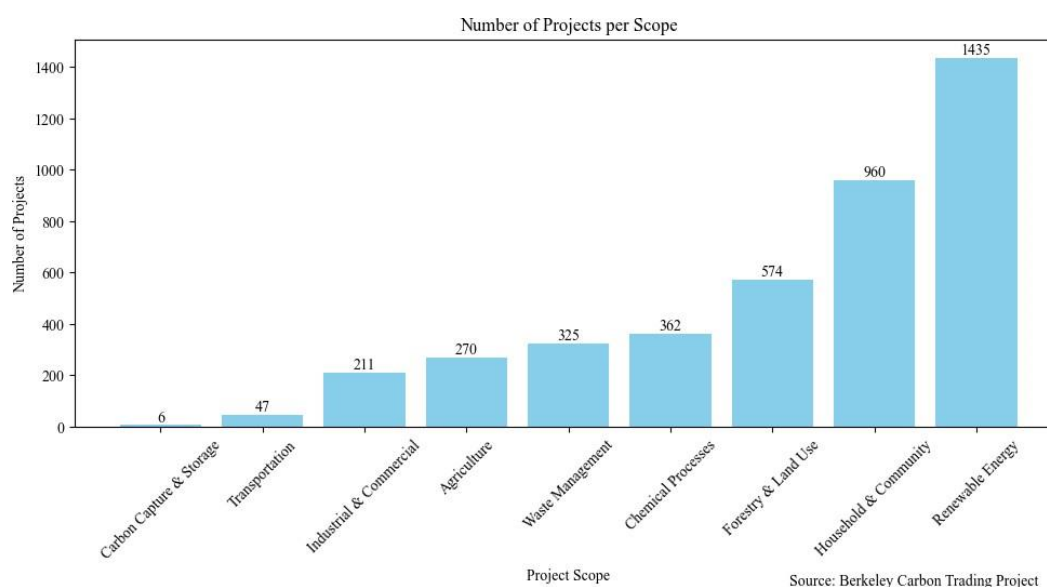
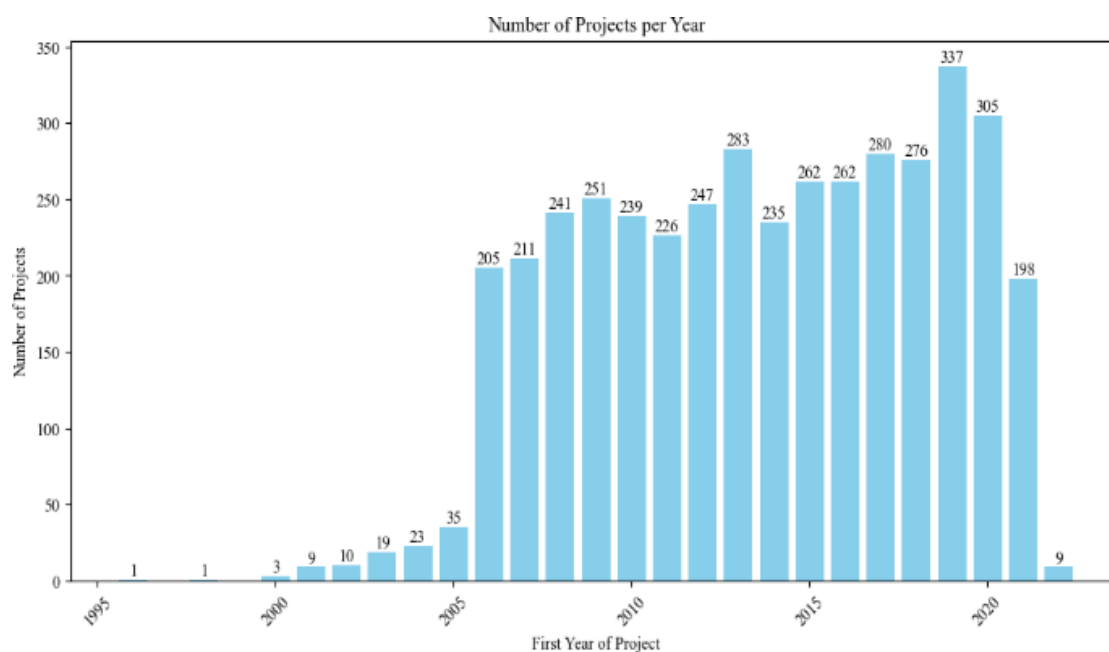


Fig. 16 – Number of Project per Scope

Effectively, renewable energy has the most significant number of projects by a large margin. The two most popular project scopes are Household & Community, with 960 projects, and forestry and land use, with 574 projects. Carbon Capture & Storage only has six projects, and Transportation 47, making this analysis less significant for these scopes, which we will not consider further. The lack of more projects in these scopes might be explained by the increased technical nuances in their developments, as they are more complex and costly to implement than most.

Next, a temporal analysis of the number of new projects per year proceeded, with the intent of capturing any relevant investment trends (see Figure 17). New projects steadily increased from 2006 to 2019 but have declined since then. This culminates in only nine projects being brought to life in 2022, a number only matched at the beginning of the decade.

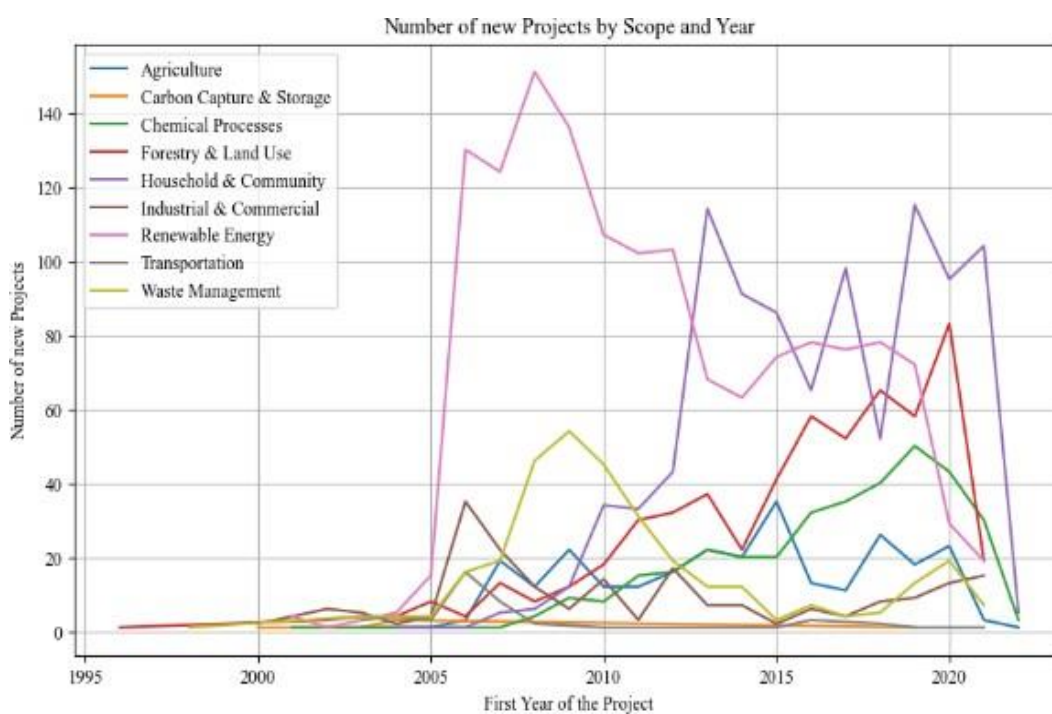


Source: Berkeley Carbon Trading Project

Fig. 17 – Number of Project per Year

These findings show that the VCM has been declining in popularity. Demand and the supply of new projects have slowed down due to recent wrongdoing and subsequent lack of trust, highlighted in Section 4.

In a similar yet different analysis, these new projects per year were categorised into different scopes. Analysing the adoption trend for various scopes (Figure 18) can provide valuable insights for Celfocus when deciding the types of projects to consider accepting on their platform. Understanding which scopes are gaining popularity or being less utilised can help strategise and align project acceptance criteria with current trends in project adoption. One can see that renewable energy projects were trending down long before the crash started in 2019. The additionality principle can explain this. With advancements in technology, the profitability of renewable energy projects has increased significantly, reducing reliance on carbon credits. This shift has made the justification of additionality more challenging, decreasing the number of projects.



Source: Berkeley Carbon Trading Project

Fig. 18 – Number of Project per Scope and Year

Household & Community is also an interesting scope. It was one of the few scopes with projects in 2022 and, since 2013, has maintained a steady trend. This might indicate the stability of this scope since its projects not only produce credits but also help develop local communities, making it more attractive in marketing terms. Also, verifying their claims by simply visiting the respective communities is much easier. A last vital conclusion to highlight is the strength of forestry and land use in recent years up until 2021. In fact, 2022 marks the only year without projects in this scope, likely because of the transparency and credibility issues that have been emerging in these credits.

Our analysis continued to inspect the average project timeline or the time between registering the project and the last time it issued credits. It is worth noting that this excludes the time to develop the project and register it (bureaucracy, document delivery, and initial verification), as no information was available. The analysis was performed for different scopes and registries. Figures 19 and 20 show the intended results.

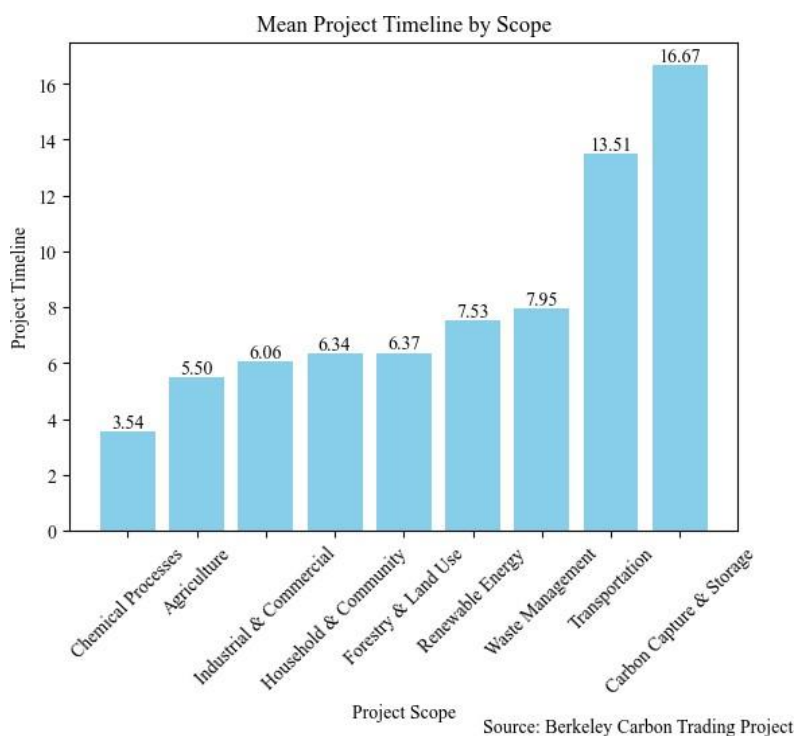


Fig. 19 – Mean Project Timeline per Scope

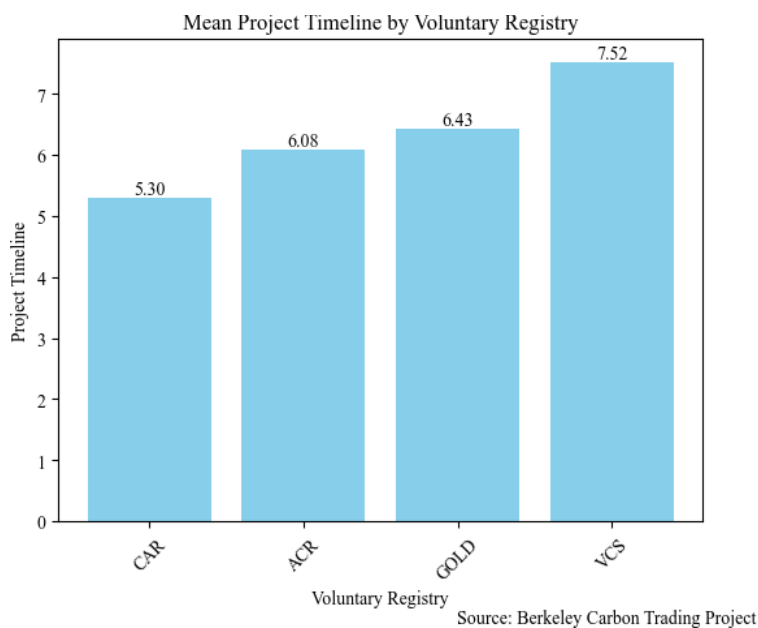


Fig. 20 – Average Project Timeline per Registry

First, it is crucial to consider that the figures underestimate a project's timeline. This happens because many projects do not issue credits yearly, meaning projects that finished issuing credits in 2022 might do it again in 2024, even though we cannot account for that. Nonetheless, there is a clear pattern within most projects scope, with projects lasting around 6 to 8 years. It is worth highlighting Chemical Processes' significantly reduced project timeline and Transportation and Carbon Capture & Storage with the highest sample average. This happens because Chemical Processes are usually straightforward projects to implement, as they do not require heavy machinery or the concession of large fields.

Regarding registries, their results are mainly explained by the project scope timelines. Verra, GOLD and ACR are the only registries with Transportation and Carbon Capture and Storage projects, pushing their averages up. On the other hand, CAR has certified many chemical processes projects, explaining their lower average.

Afterwards, the median total credits for all scopes were estimated (Figure 21), and the unitary cost of certifying a particular project per scope was estimated (Figure 22).

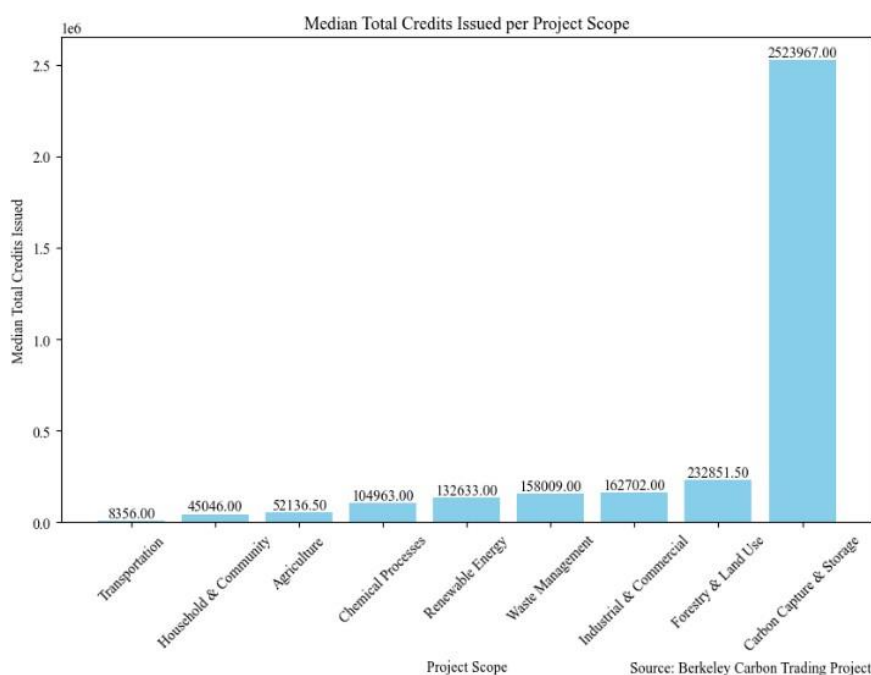


Fig. 21 – Median Total Credits Issued per Project Scope

Interestingly, Carbon Capture & Storage and Transportation now appear at opposite ends of the spectrum, with the former emerging as a clear frontrunner in credits issued. At the same time, the latter lags a lot behind. Household & Community and Agriculture are one order of greatness behind the other scopes, not issuing that many credits. Forestry and Land use appear second, partly due to the issuance of the popular REED+ credits, that are very easy to create.

To effectively consider these factors, an analysis with the median unitary cost of certifying a project for a given scope proceeded, with the results shown in Figure 22.

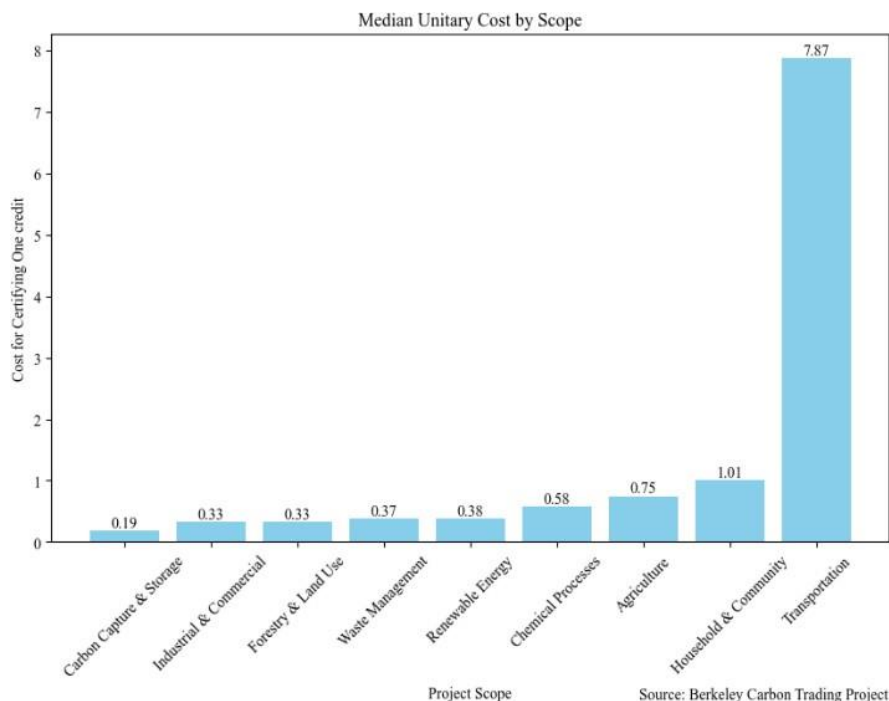


Fig. 22 – Median unitary cost per Scope

The results display exciting conclusions. Firstly, these results are highly correlated with project timelines and inversely correlated with issued credits. This happens because project timelines can be used as a proxy for fixed fees, the higher the timeline, the higher the fixed fees. If a project scope does not issue many credits, like Transportation, for example, it cannot compensate for its higher fixed fees, resulting in a higher unitary cost per scope.

Finally, an analysis was conducted on the Abatable index to determine the most favourable average scores for investment opportunities across several countries. The index comprises three scores: i) Global carbon market readiness, ii) Investment landscape, and iii) Climate, nature and people opportunity.

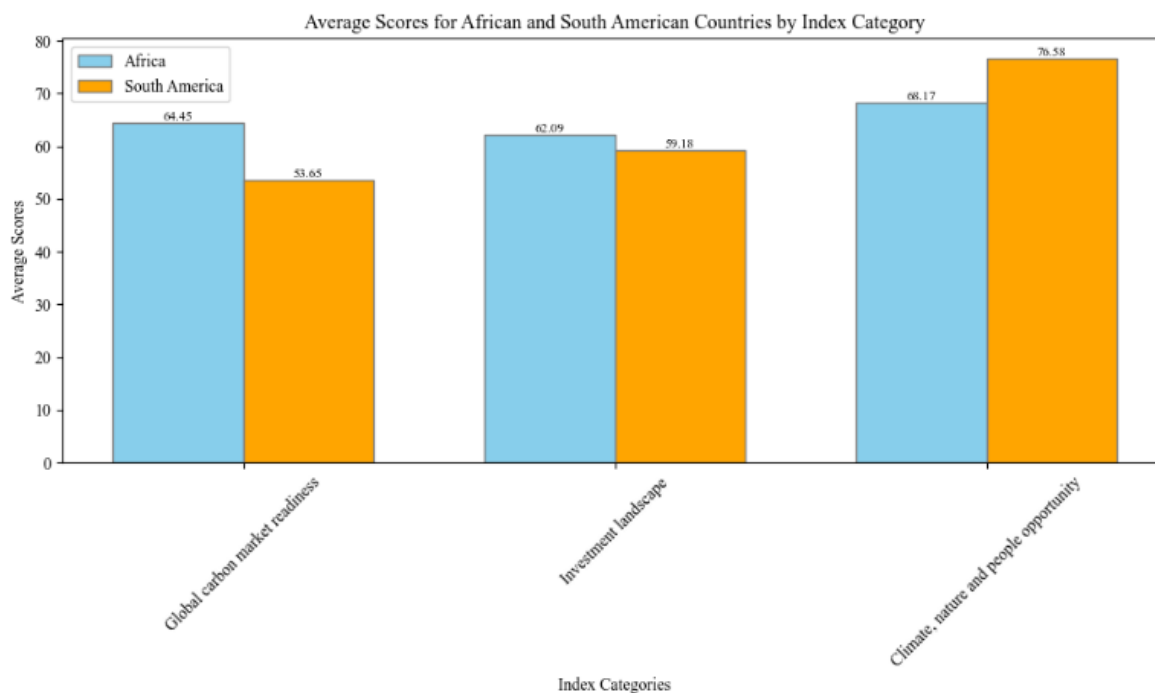


Fig. 23 – Average score per category and region

The visual representation of the average scores by country observed in Figure 23 shows that African countries slightly dominate in global carbon market readiness and investment landscape. At the same time, South America excels in climate, nature, and people opportunities.

Ultimately, the decision to prefer one over the other will depend on the weight given to each category.

Following this, a boxplot was employed to visualise potential outliers within the dataset (Figure 24). This approach aids in identifying countries that significantly stand out, positively or negatively, across all categories. Effectively, only one positive outlier was detected in Investment Landscape, with that country being Uruguay, which scored 91.

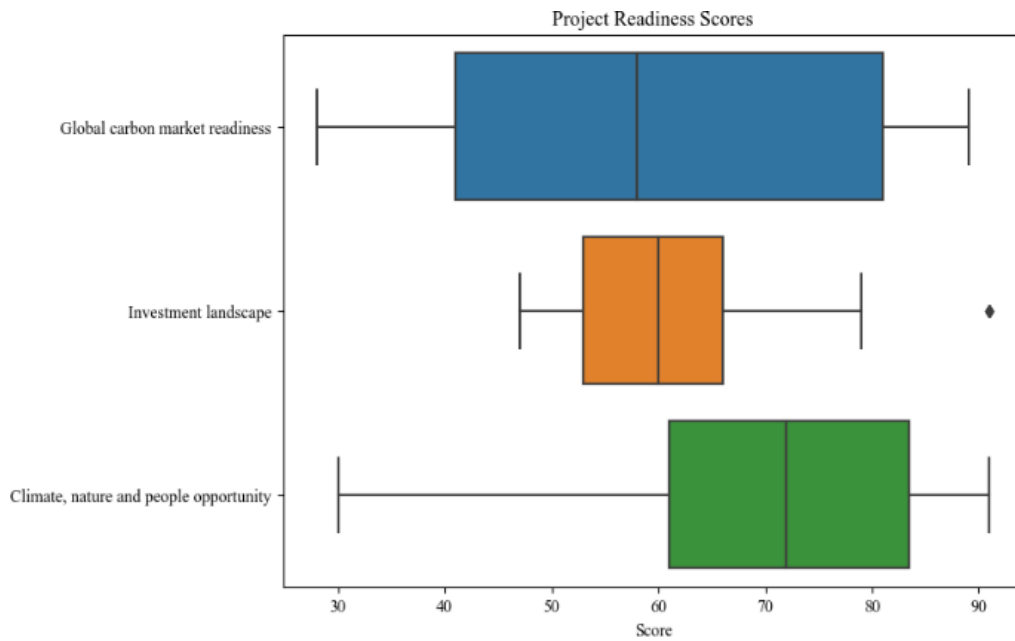
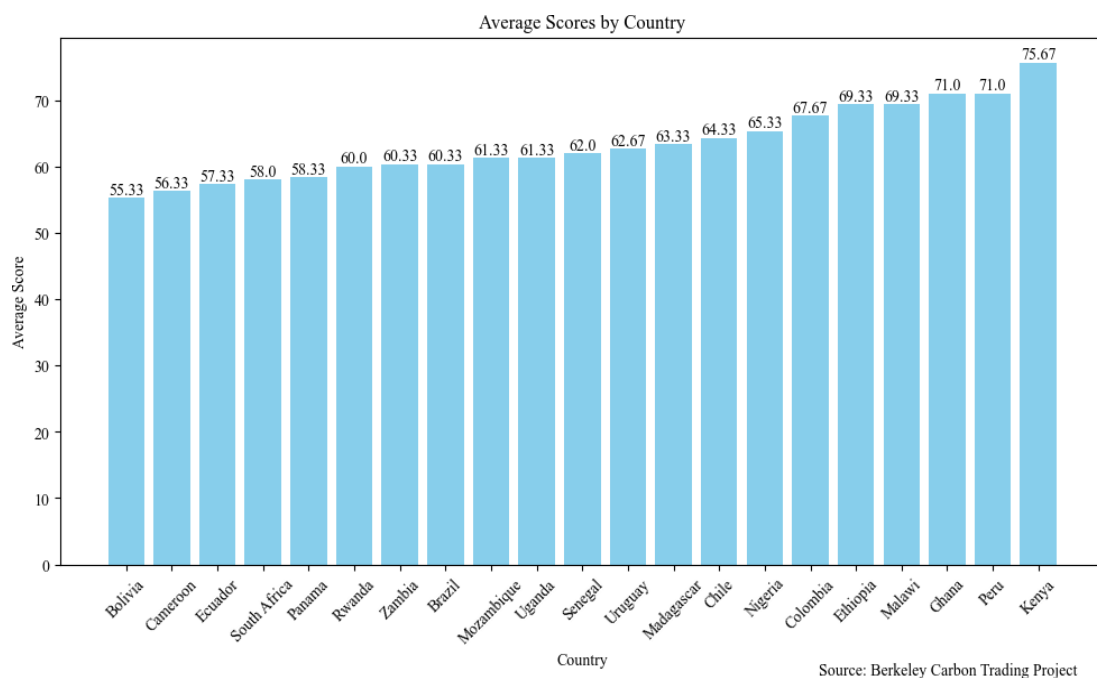


Fig. 24 – Boxplot

Finally, the analysis is concluded with Figure 25, showing the average scores by country when considering that every category has an equal weight.



Source: Berkeley Carbon Trading Project

Fig. 25 – Average Scores by Country

Kenya emerged as the best country to develop carbon projects in, with an average score of 75.67, and Bolivia was the worst, with an average of 55.33. Overall, Africa averages four countries in the top 5, while South America only has one, clearly showing a preference for African based projects.

6 Discussion

The current state of the Voluntary Carbon Market (VCM), as described by Espenan (2023), faces numerous challenges stemming from its centralised structure, lack of standardisation, and issues with transparency and credibility. The existing market dynamics contribute to inefficiencies, manipulation, and a lack of reliability in offsetting greenhouse gas emissions, which leads to a need for substantial improvements and regulatory interventions.

At its core, the VCM faces critical issues due to centralised control held by registries, allowing them to create and approve carbon sequestration methodologies without adequate regulatory oversight. This lack of standardised procedures fosters unhealthy competition, leading to potential manipulation in credit verification. Registries, acting independently, develop rules and issue carbon credits, profiting from each project they endorse. The involvement of Validation and Verification Bodies, which act by registries' rules, further blurs the lines of impartial validation, creating conflicts of interest.

The market's lack of transparency and education aggravates these problems, with carbon credit buyers often misled by the overselling of credits without compromise to reduce emissions. This misrepresentation undermines the credibility of claims of carbon neutrality, or environmental responsibility companies make. Moreover, the absence of incentives for smaller quantities of carbon credits discourages genuine efforts in emission reduction.

The complexities surrounding methodologies, particularly in estimating emission reductions accurately, contribute to the market's unreliability. The industry's lack of structured education and training programs further perpetuates the issues, leading to inexperienced personnel and a trial-and-error approach by companies.

The divergence in market forecasts from different analysts, as noted by White, Rathi, and Pogkas (2023), exemplifies this uncertainty and lack of uniformity in the VCM. This lack of quality assurance, alongside the debate on initiatives like REDD+ and the concept of additionality, underscores the market's dubious nature.

Governments, especially in the EU, are acting to address these issues through regulatory frameworks emphasising project quality, quantifiable benefits, long-term sustainability, and contribution to climate goals. This shift aims to ensure carbon credits' credibility and stimulate the emergence of reliable certification bodies. However, despite these efforts, the VCM's reliance on developing projects in regions with softer regulations reveals a disconnect in achieving global emission reduction goals.

Blockchain technology offers a potential solution to enhance transparency, traceability, and credibility within the VCM. However, scalability and interoperability challenges must be addressed for a successful integration in the market.

The analysis explored several trends in many different types of projects to understand which projects are more popular and are issuing more credits. Notably, while renewable energy and forestry and land use show signs of waning popularity and demand, household and community credits emerge as an exceptionally reliable credit type, justifying their higher-than-average certification cost.

When considering investment prospects in Europe, South America and Africa, African projects demonstrate higher readiness, preparedness, and a lower risk profile for carbon project investments. However, South America remains the most influential region for reducing GHG emissions while fostering community benefits. Specifically, countries like Kenya and Peru emerge as the best locations within their respective regions for the development of carbon projects. Additionally, Uruguay is an outlier in South America for its favourable investment

landscape and outstanding environmental conditions. Lastly, there is Europe, hiding under the umbrella of other markets. While being more technologically developed, it does not attract many projects. Nonetheless, being one of the regions starting to advance in policy and regulation, it may open a new window for new investors and buyers, in places like the United Kingdom and Sweden, as identified per the analysis.

7 Limitations

Despite the comprehensive mixed-method approach undertaken in this project, certain limitations must be acknowledged. The qualitative research, relying on interviews with voluntary carbon market stakeholders, faced challenges in securing broad participation, with many interviewees' requests being rejected or yielding no response. Despite having a structured script, subjectivity in the qualitative data analysis introduces the potential for varied interpretations and biases. Another notable limitation arises from the data constraints encountered during the research process, particularly in the absence of information on selling prices in the over-the-counter market and project development costs. It is imperative to note that the research focused on project scopes and regions does not sufficiently consider the influence of external factors, such as regulatory changes or geopolitical events, that can significantly alter the dynamics of the voluntary carbon market. A further examination of these factors is needed for a full and comprehensive understanding of the market.

8 Conclusion

The VCM needs renovation. The old market model struggles for transparency, credibility, and education, reflected in the downtrend movement in the number of projects and credits emitted. The VCM faces multifaceted challenges that require regulatory interventions, educational initiatives, technological advancements, and industry-wide collaboration to ensure credibility, transparency, and efficacy in mitigating greenhouse gas emissions.

Local projects and initiatives, when combined with advanced technologies like blockchain, may hold the key to restructuring the market in a way that fosters trust, enhances transparency, and creates real benefit to the environment. This work project helped Celfocus to acquire the necessary input to further develop their solution, alongside interesting investment prospects in other regions as well. All in all, despite its imperfections, the VCM (Voluntary Carbon Market) remains as one of the most powerful instruments that can be leveraged to address the climate crisis.

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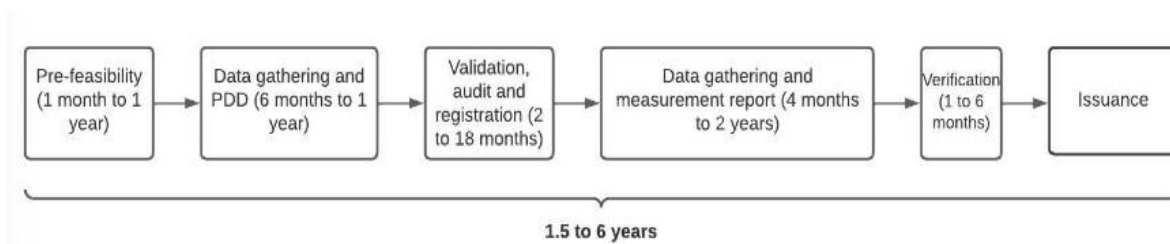
10 Appendix

Appendix 1: Carbon Management Ecosystem



Source: Carbonbase Ecosystem Diagram, 2022, compiled from Bloomberg, World Resource Institute, World Bank sources

Appendix 2: Certification Process



Source: The Voluntary Carbon Market: Market Failures and Policy Implications, 2023

Appendix 3: Certification form

VERRA

Verified Carbon Standard

Certificate of Verified Carbon Unit (VCU) Retirement

Verra, in its capacity as administrator of the Verra Registry, does hereby certify that on 27 Jan 2022, 100 Verified Carbon Units (VCUs) were retired on behalf of:

Project Name
"Weyerhaeuser Uruguay" Forest Plantations on degraded grasslands under extensive grazing

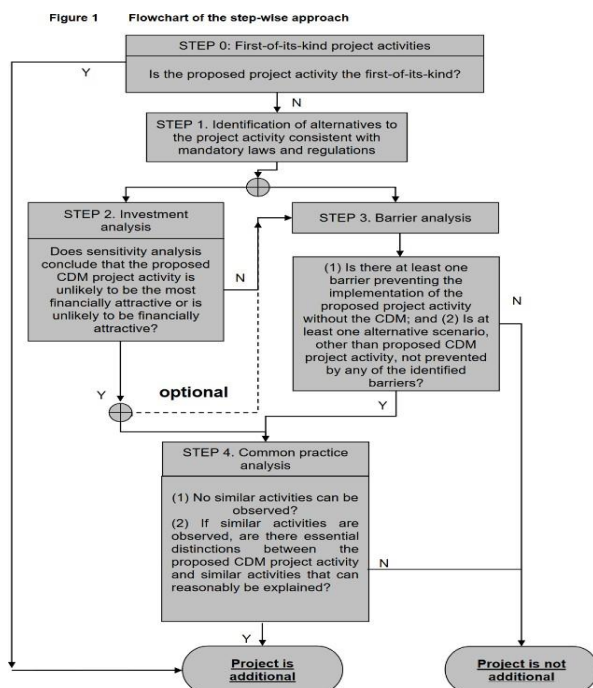
VCU Serial Number
9857-148501148-148501247-VCS-VCU-261-VER-UY-14-960-01012009-31122009-0

Additional Certifications

Powered by **APX**

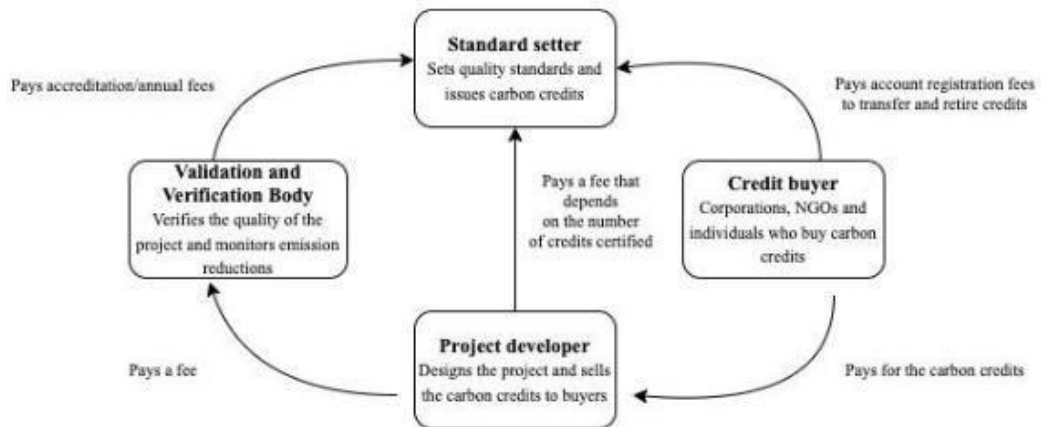
Source: Verra (<https://verra.org/>)

Appendix 4: Additionality flow chart



Source: Clean Development Mechanism (CDM) TOOL01- Tool for the demonstration and assessment of additionality

Appendix 5: Value chain



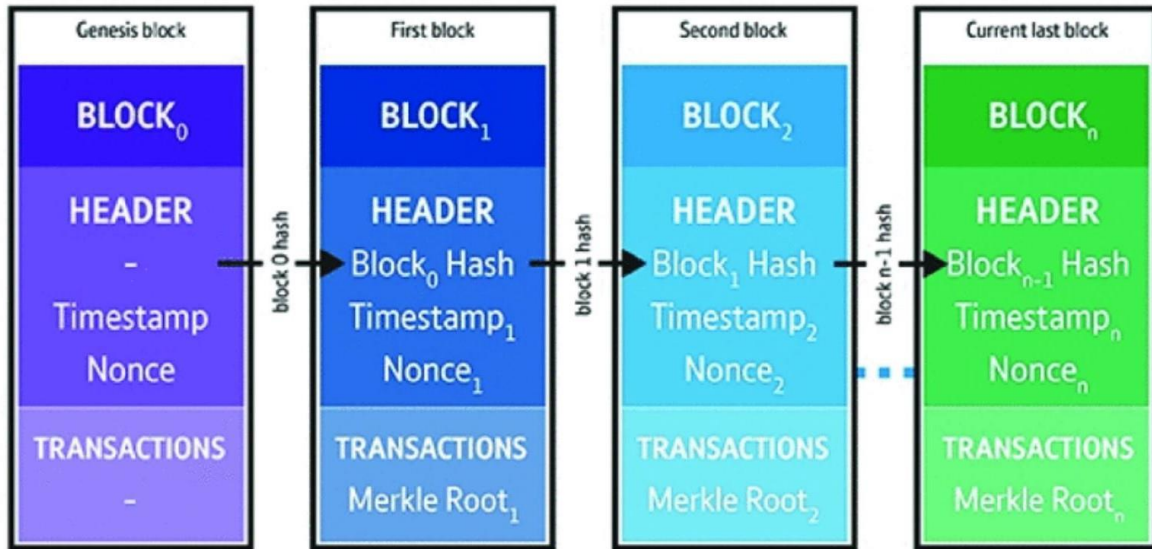
Source: The Voluntary Carbon Market: Market Failures and Policy Implications, 2023

Appendix 6: Methodology compensation rates

# of VCUs issued	USD / VCU
1-1,000,000	USD 0.02
1,000,001-2,000,000	USD 0.018
2,000,001-4,000,000	USD 0.016
4,000,001-6,000,000	USD 0.012
6,000,001-8,000,000	USD 0.008
8,000,001-10,000,000	USD 0.004
10,000,000-60,000,000	USD 0.002

Source: VCS Program-Fee-Schedule-v4.3-FINAL, 2023

Appendix 7: The operation principle of blockchain



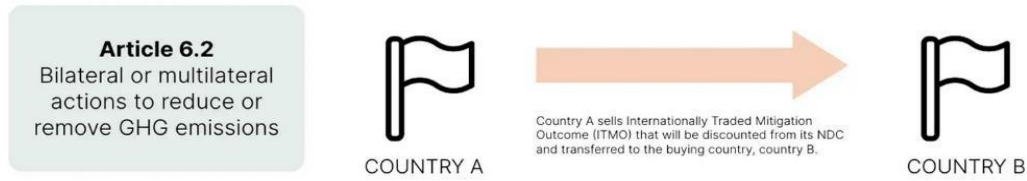
Source: <https://ieeexplore.ieee.org/document/8899450>

Appendix 8: Nori Certification Form



Source: Nori (<https://nori.com/>)

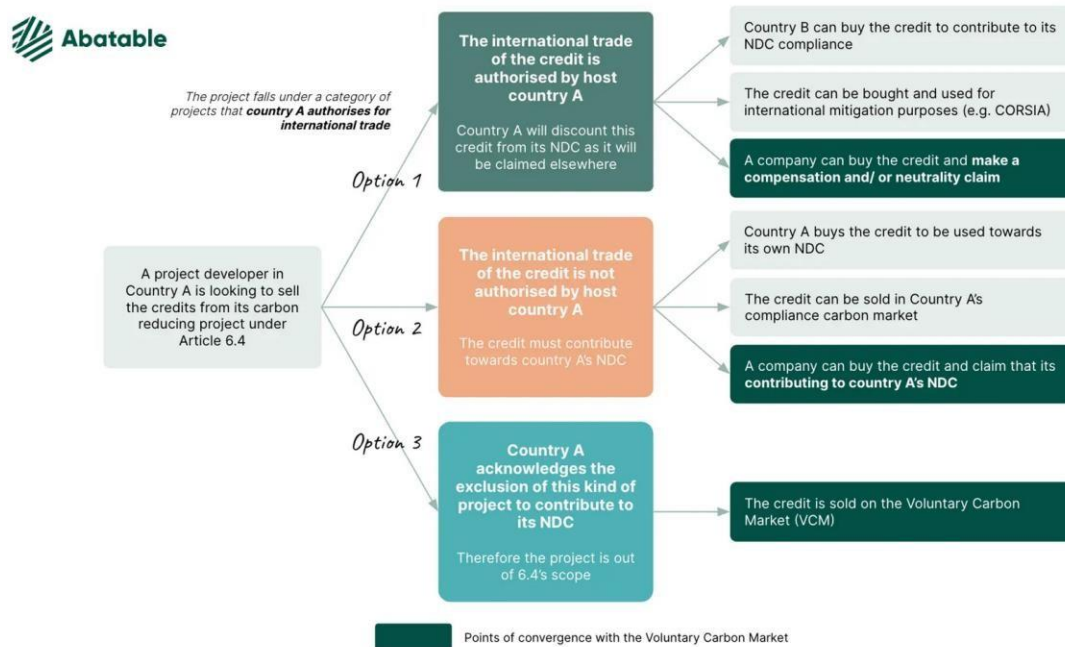
Appendix 9: Emissions Reduction Trading Example



Source: Abatable, 2022:

<https://cdn.sanity.io/images/uxhxwji3/production/0e40627826c5c8b9e44131e583e285f215f1d1d8-1671x999.png>

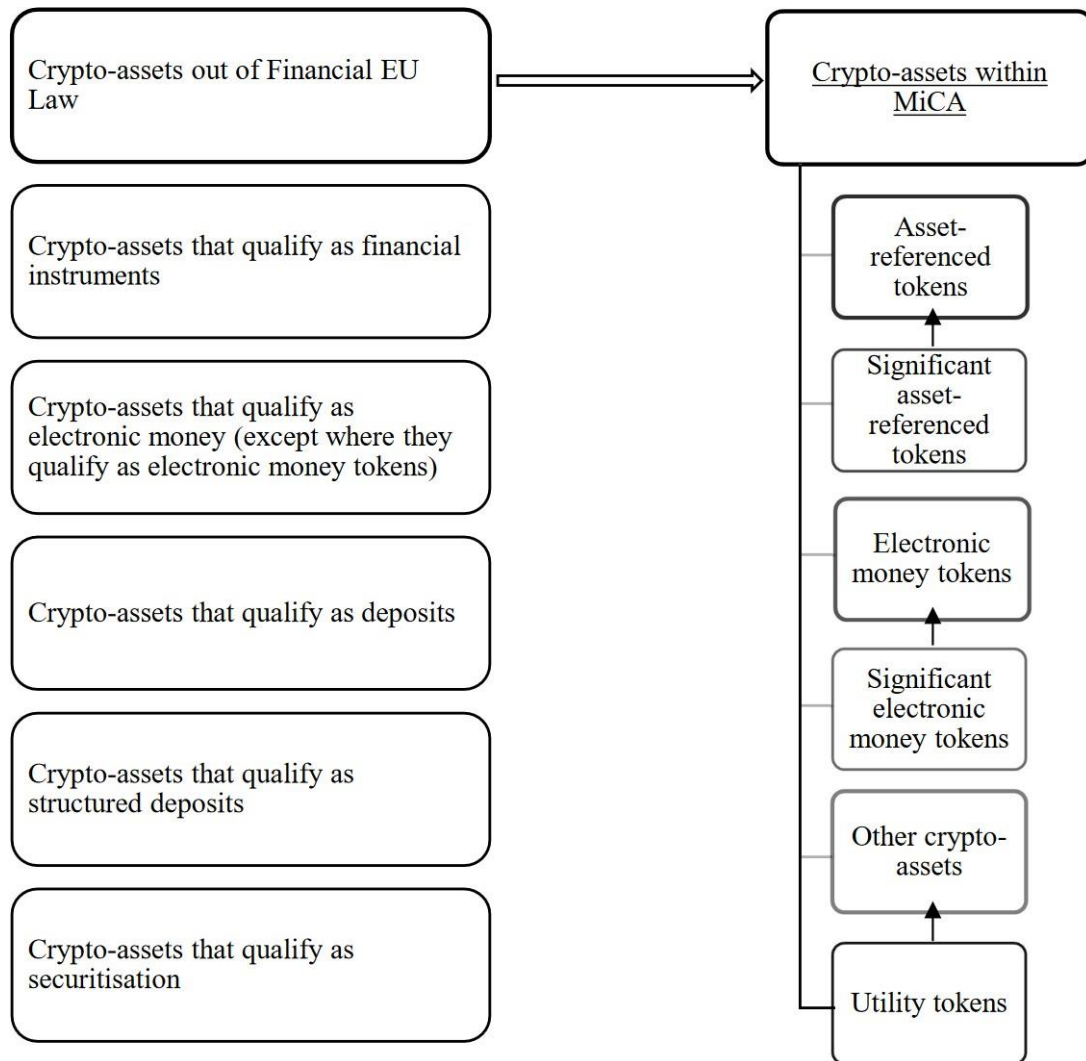
Appendix 10: Structure of credits that count towards NDC



Source: Abatable, 2022:

<https://cdn.sanity.io/images/uxhxwji3/production/0e40627826c5c8b9e44131e583e285f215f1d1d8-1671x999.png>

Appendix 11: Taxonomy of crypto assets under MiCA



Source: Maia, Santos (2021)

Appendix 12: Semi Structured Interviews

Position	Company/ Sector	Duration
Data Analyst	Project Developer	1h
Director	Project Developer	40 min
Professor	Project Developer & Methodology Developer	45min
Director	Project Developer & Methodology Developer	30min
Lawyer	Policy and Regulation	2h
Senior Manager Program Secretariat	Verra	1h

Appendix 13: Interview Script

Job/Company related

How are you involved in the voluntary carbon market?

How does one assess the quality of carbon credits?

What's your company's investment philosophy and criteria when deciding to fund carbon offset projects or project developers? Are there any immediate red-flags easy to spot? –
Quality

How do project developers interact with marketplaces? What is the process that a project developer goes through?

Project Development and general topics

What difficulties arise from being a project developer? What is the hardest thing to deal with?

Marketplaces usually provide a platform that allows project developers to connect with capital providers, in percentage what's the cost of developing a project?

Do you have any expertise in credit prices from working in the industry? If so, do you know on average how much credit should be sold for any given scope if a project wants to make a profit?

Marketplaces (personal view)

What is the key factor in a good voluntary carbon marketplace?

What is missing from existing marketplaces?

In your thought, do you think a blockchain solution could better the VCM?

Should a marketplace have a direct impact on the quality verification of carbon credits?

In your view, what is the biggest problem with VCM at the moment and how can it be fixed?

Appendix 14: Interviews Content Analysis

Quality	"Verra has been a standard setter for a long time it's one of the oldest in the market and it's still in a error and learn method"
Clear_Market_Processes	"Our work follows the project documentation and then we have close to no contact with project developers"
Legislation_blocks	"There's Local, problems as people trying to take illegally ownership of fields"
Costs_&_Price_information	"There are four phases of a project that require a monetary incentive to start, project design, implementation, certification, and verification, where undoability the more costly side is the implementation"
Breakeven_point	"Project vary a lot based on region and type there's no clear point"
Key_market_factors	"In 2021 from 10 credist issued 7 were from Verra", "Vera is actively reaching out to governments that are regularizing the VCM"
Validation_&_Verification	"The company interacts more with the vvb's to transparency"
Blockchain_Solution	"In 10 to 15 years there will be a unification of registries"
Key_market_problems	"3 to 10 years to get the carbon credits", "Lack of a marketplace"