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Beyond Sustainability? A Taxonomy of Blockchain Applications in Regenerative Finance

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Abstract

This study examines the applications of blockchain technology in the field of regenerative finance (ReFi) and presents a comprehensive taxonomy of blockchain-based ReFi applications. The objective is to provide a basis for future evaluations of the applications' potential to create regenerative financial and economic systems. Using a qualitative and exploratory research approach based on the Gioia methodology (Gioia et al. 2013), this study leverages data from the ReFi DAO database to categorize the various blockchain implementations in the emerging ReFi ecosystem. The findings form a detailed taxonomy of 21 major blockchain application groups and eight overarching dimensions, providing in-depth insights into the ReFi landscape. The analysis shows heterogeneous use cases that go far beyond the use of blockchain-based carbon credit tokens, including but not limited to decentralized energy systems, impact tokens and blockchain-based polycentric governance systems. In addition, the study introduces the term "X-to-Earn" as an umbrella term for commonly used crypto-incentive based engagement models in the ReFi space that combine financial incentives with an envisioned behavioral change or action. From a theoretical perspective, this study contributes to the understanding of the ReFi ecosystem and highlights a variety of multidisciplinary research streams. In addition, it provides practitioners with novel concepts for business model innovation, alternative funding opportunities, and regulatory areas that may require enhanced regulation and monitoring in the future. This study advocates an interdisciplinary research approach to bridge the gap between the theoretical potential and practical application of ReFi applications for the development of regenerative, decentralized and equitable systems.

Dissertation Title: Beyond Sustainability? A Taxonomy of Blockchain Applications in Regenerative Finance

Author: Friedrich-Philipp Wazinski

Keywords: Blockchain, Regenerative Finance, Distributed Ledger Technology, Taxonomy, ReFi

Sumário

Este estudo examina as aplicações da tecnologia blockchain nas ReFi e apresenta uma taxonomia abrangente. Este estudo visa estabelecer uma base para a avaliação futura do potencial das aplicações para gerar sistemas financeiros e económicos regenerativos. Este estudo utiliza uma abordagem de pesquisa qualitativa e exploratória, especificamente a metodologia Gioia (Gioia et al., 2013), para analisar dados da base de dados ReFi DAO. O objetivo é classificar as diferentes implementações de cadeias de blocos no âmbito do ecossistema ReFi emergente. O estudo apresenta uma taxonomia abrangente de 21 grupos de aplicações de cadeias de blocos proeminentes e oito dimensões abrangentes, oferecendo uma visão detalhada do panorama da ReFi. A análise revela diversos casos de uso que vão além da utilização de tokens de crédito de carbono baseados em blockchain. Isso inclui sistemas de energia descentralizados, token de impacto e sistemas de governança policêntricos baseados em blockchain. O estudo introduz o termo "X-to-Earn" como um rótulo abrangente para modelos de engajamento baseados em cripto-incentivos no espaço ReFi. Esses modelos combinam incentivos financeiros com uma mudança ou ação comportamental desejada. Este estudo melhora a compreensão académica do ecossistema ReFi e identifica novos fluxos de investigação multidisciplinar. Além disso, oferece aos profissionais novos conceitos para modelos de negócio inovadores, opções de financiamento alternativas e potenciais áreas de regulação e monitorização no futuro. Este estudo propõe uma abordagem de investigação interdisciplinar para colmatar a lacuna entre o potencial teórico e a aplicação prática das aplicações ReFi para o desenvolvimento de sistemas regenerativos e descentralizados.

Título da dissertação: Para além da sustentabilidade? Uma taxonomia das aplicações de blockchain em finanças regenerativas

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Palavras-chaves: Blockchain, Finanças Regenerativas, Tecnologia de Registo Distribuído, Taxonomia, ReFi

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List of Abbreviations

| | |
|---------|--|
| AI | Artificial Intelligence |
| BCT | Base Carbon Tonne |
| CO2 | Carbon Dioxide |
| DAO | Decentralized Autonomous Organization |
| DeFi | Decentralized Finance |
| DePIN | Decentralized Physical Infrastructure Networks |
| DiD | Decentralized identifier |
| dMRV | digital Measurement, Reporting, and Verification |
| dNFT | dynamic Non-Fungible Tokens |
| dREC | digital Renewable Energy Certificate |
| EVM | Ethereum Virtual Machine |
| FinTech | Finance Technology |
| IoT | Internet of Things |
| MWh | Megawatt Hour |
| MRV | Measurement, Reporting, and Verification |
| NCT | Nature Carbon Tonne |
| NFT | Non-Fungible Token |
| PoA | Proof of Authority |
| PoG | Proof of Generation |
| PoH | Proof of History |
| PoS | Proof of Stake |
| REC | Renewable Energy Certificate |
| ReFi | Regenerative Finance |
| SDG | Sustainable Development Goal |
| UBI | Universal Basic Income |

1 Introduction

In an era where traditional financial and economic systems are increasingly criticized for perpetuating ecological destruction and economic inequality (Clark et al. 2018; Foster et al. 2011), the concept of Regenerative Finance sets itself the goal to represent a novel, transformative, and promising paradigm for change. Building on the principles laid out by Fullerton and Lovins (2009) and Fullerton (2015) - even before the popularization of blockchain and decentralized technologies - ReFi aims to drive a radical shift towards decentralized, inclusive economic systems (Bryant et al. 2024). These systems aim to promote ecological restoration, community empowerment and social equality and provide tools to address the issue of the tragedy of the commons (Hartley and Rennie 2022; Schletz et al. 2023). ReFi combines regenerative and ecological economic concepts with digital technologies including but not limited to Web3 technologies, Internet-of-Things (IoT), and Artificial Intelligence (AI), potentially setting the stage for a fundamental evolution in economic and ecological practice (Bryant et al. 2024; Hartley and Rennie 2022; Schletz et al. 2023).

One key enabler of this regenerative, technology-based movement is blockchain technology, including its concepts and applications such as smart contracts, decentralized autonomous organizations (DAO), cryptocurrencies, and tokenization (Bryant et al. 2024), all of which utilize a decentralized and secure ledger system enhanced by cryptographic mechanisms (Christidis and Devetsikiotis 2016; Nakamoto 2008). Blockchain technology facilitates transparent, tamper-proof transactions and automates trust (Christidis and Devetsikiotis 2016; Nakamoto 2008), which might be important features for transparent environmental management (Howson 2021), decentralization and equitable systems (Bryant et al. 2024).

Despite its potential, ReFi remains under-conceptualized, as evidenced by the scarcity of academic literature. According to a handful of scholars, ReFi is a movement that uses digital technologies such as blockchain to improve the management of shared resources, democratize finance, and create sustainable economic models through digital monitoring, reporting, verification (D-MRV), and tokenization of assets, mainly carbon credits (Hartley and Rennie 2022; Schletz et al. 2023; Sorensen 2023). However, the existing literature reveals a significant gap in terms of a widely accepted definition and comprehensive understanding of ReFi's applications, implications, and mechanisms, as well as the application and use of key web3 technology, blockchain. The absence of extensive research and comprehensive understanding may pose a significant obstacle to fully harnessing the potential of ReFi in addressing pressing

global issues such as climate change, economic instability, social injustice, and the tragedy of the commons.

In response to the call by Schletz et al. (2023) to address this gap and expand ReFi research beyond the use of blockchain-based carbon credits, this study aims to establish a taxonomy of blockchain applications in Regenerative Finance. Essentially, it addresses the following research question:

RQ1: What are the primary applications of blockchain technology in Regenerative Finance and how can they be categorized into a comprehensive taxonomy?

To provide a thorough response to the research question presented in this study, an exploratory research approach is employed, utilizing the Gioia method to construct a comprehensive taxonomy (Gioia et al. 2013). By leveraging a structured approach to qualitative data analysis, the study examined a dataset of 90 whitepapers from 88 companies within the ReFi space. Adhering to the guidelines set forth by Gioia et al. (2013), the analysis reveals a detailed taxonomy of blockchain applications in ReFi, including 21 distinct application groups and eight high-level dimensions. This taxonomy provides a comprehensive overview of the use of blockchain in the ReFi ecosystem, benefiting both researchers and practitioners by enhancing the comprehension of the ReFi ecosystem and regenerative digital markets. Furthermore, the taxonomy provides a framework for exploring potential areas of study for future interdisciplinary research in the field of ReFi. From a managerial perspective, it provides insights into the development of innovative business models, alternative funding options, and financial instruments. In addition, the study highlights certain application groups that may require increased regulatory oversight and management.

The following sections of the research are organized as follows: Section II provides an overview of the current research on ReFi. Section III outlines the methodology used in the study and introduces the Gioia method, while Section IV delves into the various components of the taxonomy, providing an in-depth explanation. Section V comprises a thorough examination and evaluation of the findings. Section VI provides a summary of the study's findings and emphasizes their significance for both theory and practice. The section also acknowledges the study's limitations and suggests areas for further research.

2 Theoretical Background

2.1 Regenerative Finance

Regenerative finance is characterized in academic literature as either a movement (Issa et al. 2024; Schletz et al. 2023; Sorensen 2023), a strategy (Shih et al. 2023) a set of tools and ideas (Ethereum Foundation 2024) or alternative financial system (Viditgalav 2023), and emerged between 2020 and 2021 (Hartley and Rennie 2022). ReFi can be considered a multidisciplinary and multifaceted approach (Sorensen 2023), situated at the convergence of regenerative and ecological economic theory, decentralized finance, Web3 technologies, Web3 communities, and environmental studies (Hartley and Rennie 2022; Hoopes et al. 2023; Issa et al. 2024; Schletz et al. 2023).

Further, the concept of ReFi is rooted in the research conducted by Fullerton (2015) and Fullerton and Lovins (2009) on regenerative capitalism and the principles of regenerative economies (Hartley and Rennie 2022; Schletz et al. 2023). Their research emphasizes the need for a more decentralized system, a re-evaluation of the traditional financial system, and a transition from exploitative systems to economic models that promote sustainable and regenerative development, ecological restoration, and community empowerment (Fullerton 2015; Fullerton and Lovins 2009). As illustrated in Figure 1 by Reed (2007) and Cheikosman 2022, the idea of regenerativity goes beyond the concept of sustainability and is made more theoretically and practically tangible by Fullerton (2015) with the concrete principles of regenerative vitality. The eight encompass I. Right Relationship, II. Views Wealth Holistically, III. Innovative, Adaptive, Responsive, IV. Empowered Participation, V. Honors Community and Place, VI. Edge Effect Abundance, VII. Robust Circulatory Flow, VIII. Seeks Balance,, and represent an overarching and coherent pattern for holistic regenerative system thinking.¹

¹ For a comprehensive description of the principles, see Fullerton (2015), p. 39 ff.

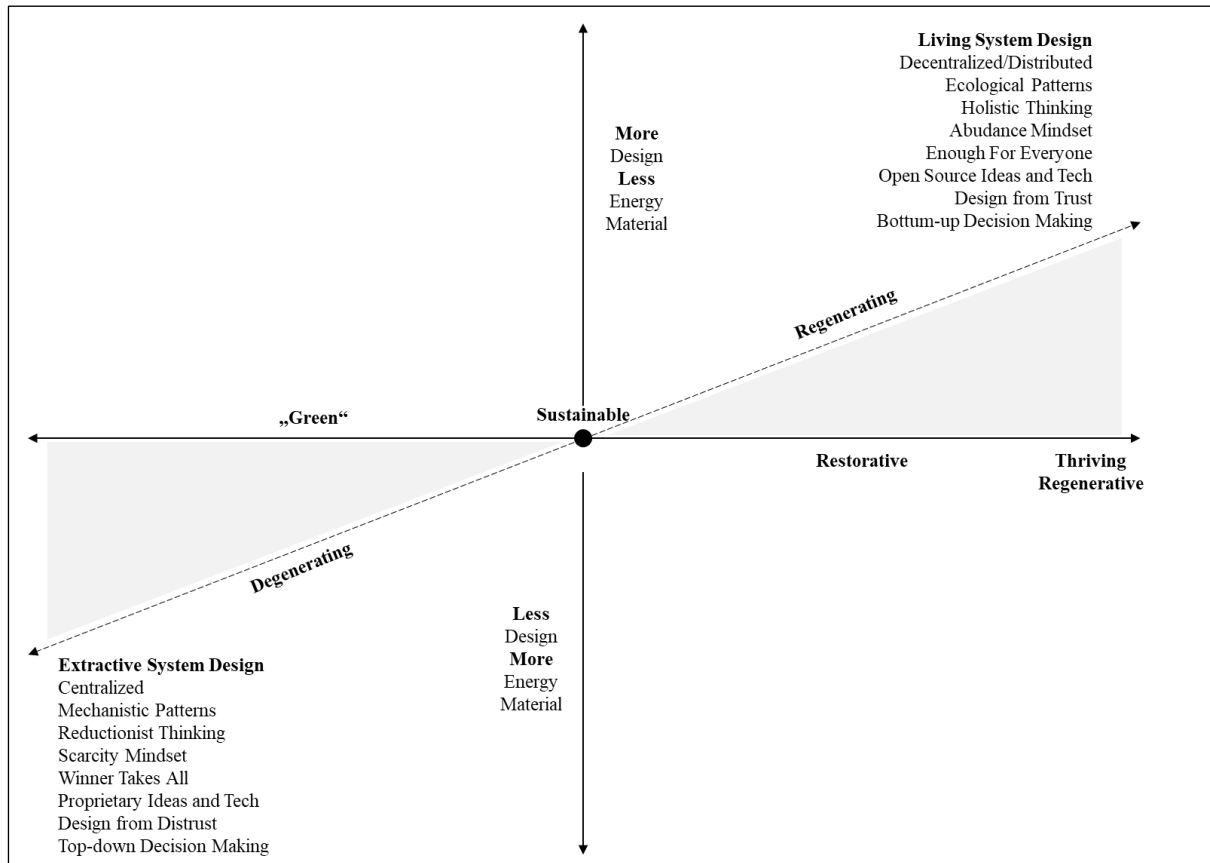


Figure 1: Evolving ecological economics
Source: Adapted from Reed (2007) and Cheikosman (2022)

Contemporary discourse extends these foundational ideas. Schletz et al. 2023 describe ReFi is a decentralized initiative that seeks to enhance the governance of common pool resources and financing by leveraging digital technologies like blockchain and Web3 applications. Furthermore, Schletz et al. (2023) propose a three-tier ReFi stack that forms the basis of the ReFi ecosystem. This stack comprises D-MRV applications, the tokenization of digital assets to foster financial democratization and the creation of new markets, and the incorporation of incentivization designs and decentralized governance as a fundamental element in ReFi. Nabben (2023) characterizes ReFi as a community that focuses on developing novel economic models for managing shared environmental resources. While, according to Issa et al. (2024), ReFi can be viewed as a community that is part of Web3. The primary objective is to leverage blockchain applications for financing and addressing global climate health challenges. In addition, Issa et al. (2024) note that ReFi is focused on establishing alternative institutions that encourage sustainability. Similarly, Hoopes et al. (2023) contend that ReFi is a concept related to the Web3 sphere, aiming to develop financial tools that enable a regenerative and inclusive economic model through the strategic use of blockchain-based tokens and economic incentives.

Hartley and Rennie (2022) perceive ReFi as an emerging movement intent on transforming the extractive economic system into a regenerative model using tokenomics-based models, incentivization schemes, and decentralized governance. They outline the movement's five motivating concepts: I) redefining values, II) facilitating access to climate action, III) enhancing data accessibility, IV) addressing global coordination failures, and V) improving carbon markets.

In a slightly different perspective, Shih et al. (2023) identify ReFi as a key advancement in sustainable finance, building on Financial Technology (FinTech) and green finance innovations. The authors argue ReFi redirects investments towards economic resilience, community well-being, and environmental protection, marking a shift from short-term profits to a sustainable and holistic financial model that favours regeneration over depletion (Shih et al. 2023).

The academic discourse surrounding ReFi typically centers on its core concept, which draws from Fullerton's (2015) theory of regenerative economy and the principles of decentralized finance. The intention is to establish a regenerative and inclusive economic system, rather than one that extracts resources (Bryant et al. 2024). Nevertheless, despite the valuable contributions made by Hartley and Rennie (2022), Hoopes et al. (2023), and Schletz et al. (2023), there remains a gap in the academic understanding of ReFi. The absence of a universally accepted definition of ReFi and a thorough grasp of its applications and mechanisms is apparent.

3 Methodology

3.1 Research Design

In this study, a qualitative, exploratory research methodology is adopted to address the formulated research question. This choice is driven by the novelty of ReFi and the limited scope of prior investigations, which collectively result in a scarce body of comprehensive knowledge in the given field (Manerikar and Manerikar 2014). Further, the research design of this study is grounded in a systematic approach and design recommendations for qualitative research studies by Gioia et al. (2013), which was previously utilized in a similar setting in the field of blockchain research by Russo-Spena et al. (2023) and Mahmud et al. (2022). The Gioia method is a fitting approach for this research, as it aims to validate established concepts, broaden existing knowledge and theories, and generate new theories and concepts through an in depth-analysis of qualitative data, as it establishes a grounded theory model that is firmly based on the collected raw data (Gioia et al. 2013; Gioia et al. 2022).

To ensure scientific rigor in this study, despite the inherent interpretive flexibility of the Gioia-method (Gehman et al. 2018; Gioia et al. 2013), the research design follows a three-fold research process recommended by Gioia et al. (2013), Gioia et al. (2022) and Magnani and Gioia (2023). This approach has been previously employed by Russo-Spena et al. (2023) in qualitative blockchain research and has been adapted for the purposes of this study. The research process is illustrated in detail in Figure 2, showcasing the three steps of I) data collection, II) data coding and analysis, and III) theorizing.

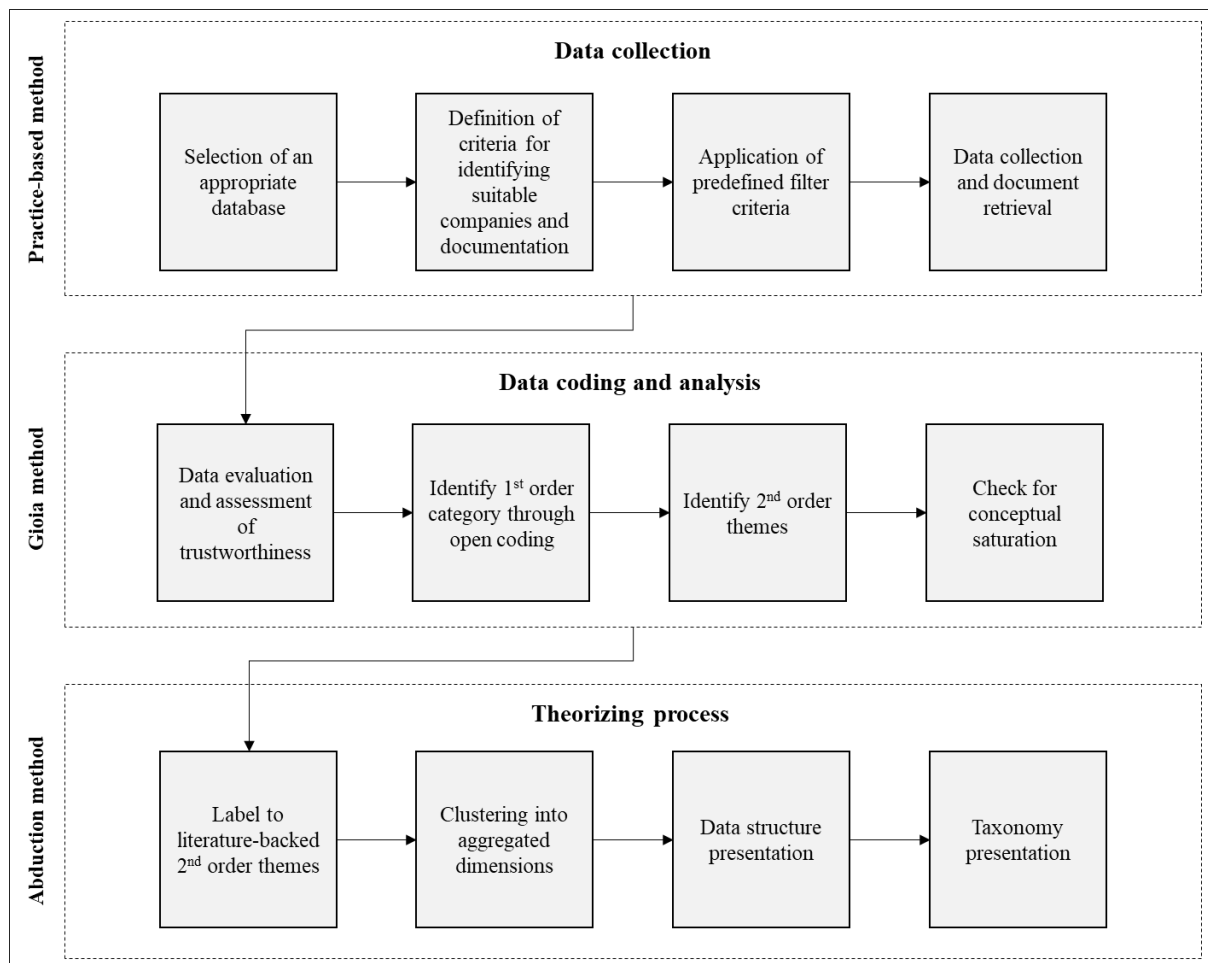


Figure 2: The research process of the study
Source: Adapted from Russo-Spena et al. (2023)

3.2 Data Collection

This study draws on a data collection approach that relies on the ReFi DAO database, a database that systematically documents organizations within the ReFi ecosystem (ReFi DAO 2024). The ReFi DAO database was similarly employed by Diaz Valdivia and Poblet (2022) as an appropriate data the basis for a comparable study on a ReFi multicase study. Between January 17th and January 19th, 2024, a total of 565 organizations were identified using the ReFi DAO database. Their websites were extracted and documented in a separate Excel file. A comprehensive filtering process was established, following the PRISMA guidelines by Liberati et al. (2009), to thoroughly evaluate the appropriateness of the organizations and corresponding documentation (see Figure 3).

Once the initial data set of organizations was established, a thorough screening process was conducted to eliminate any duplicate entries. The business status of the included organizations was verified by cross-referencing information from the company information database

Crunchbase and LinkedIn, as similarly done by Schirmer et al. (2021). Additionally, the presence of websites and English-language documents was confirmed. As part of the research process, corresponding organizations websites were manually examined to identify additional documentation, such as whitepapers or similar materials, which are a suitable basis for further qualitative analysis (Mayring 2014). The search yielded a corpus of 136 documents, which were subsequently examined for their informational content. Following the successful implementation of predetermined filters, as seen in Figure 3, the data collection yielded a corpus of 90 white papers or comparable publications, including green papers, sourced from 88 various organizations. These materials established the foundation for the subsequent data analysis process.

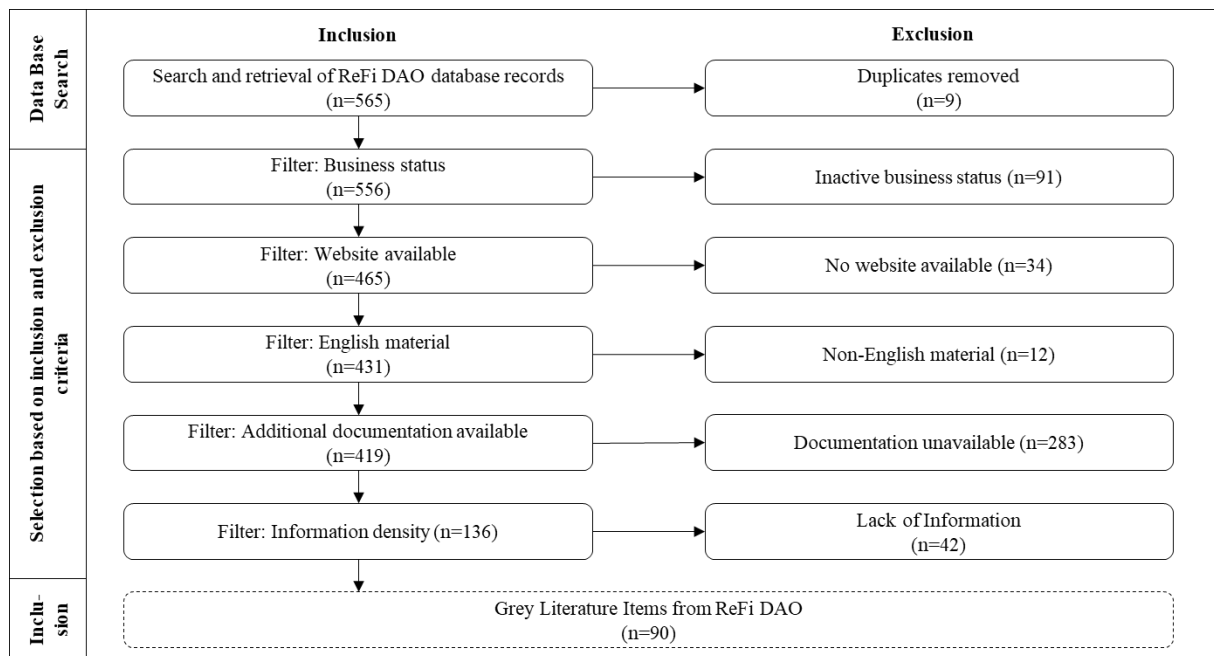


Figure 3: Structured dataset selection process

Source: Own representation

3.3 Data Analysis

For this study, a thorough textual analysis was conducted based on the discovered 90 eligible literature items that were published or updated between 2017 and 2024, as shown in Figure 4. The documents in the form of PDF or manually generated TXT files based on Notion-based whitepapers were uploaded to Atlas.ti., a software which commonly used for qualitative research projects and provides suitable tools for qualitative analysis (Frieze 2019; Mayring 2014). Following the coding recommendations by Corbin and Strauss (1990), Khandkar (2009), Vollstedt and Rezat (2019) and Saldana (2021), the papers underwent an inductive open coding process.

This approach, in accordance with the design principles established by Gioia et al. (2013), was considered appropriate for the given qualitative analysis. It enabled an initial understanding of the data and facilitated the condensation of a large amount of raw data into a summarized format (Saldana 2021; Thomas 2003; Vollstedt and Rezat 2019).

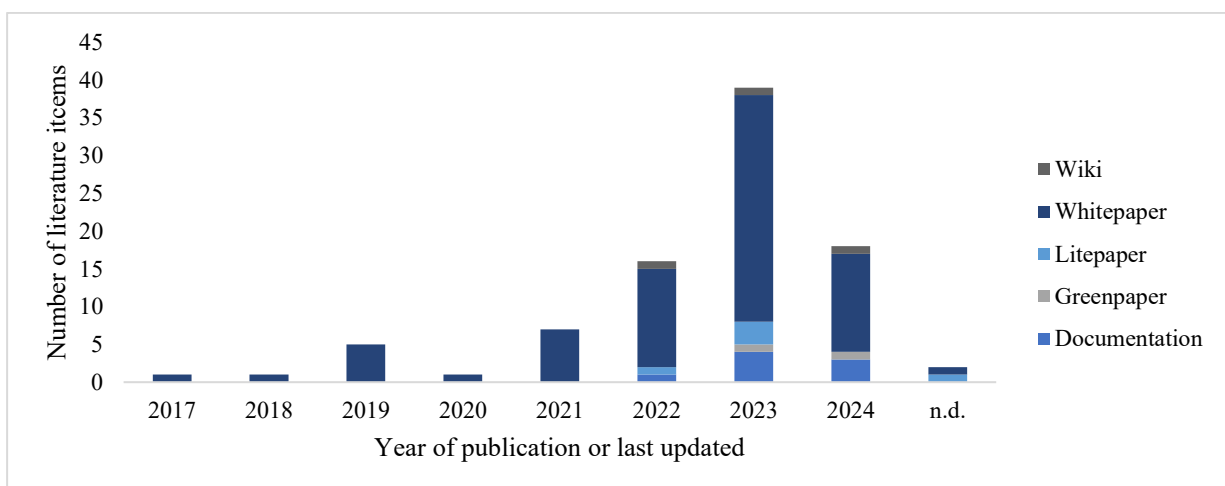


Figure 4: Analyzed literature items by year and type of publication
Source: Own representation

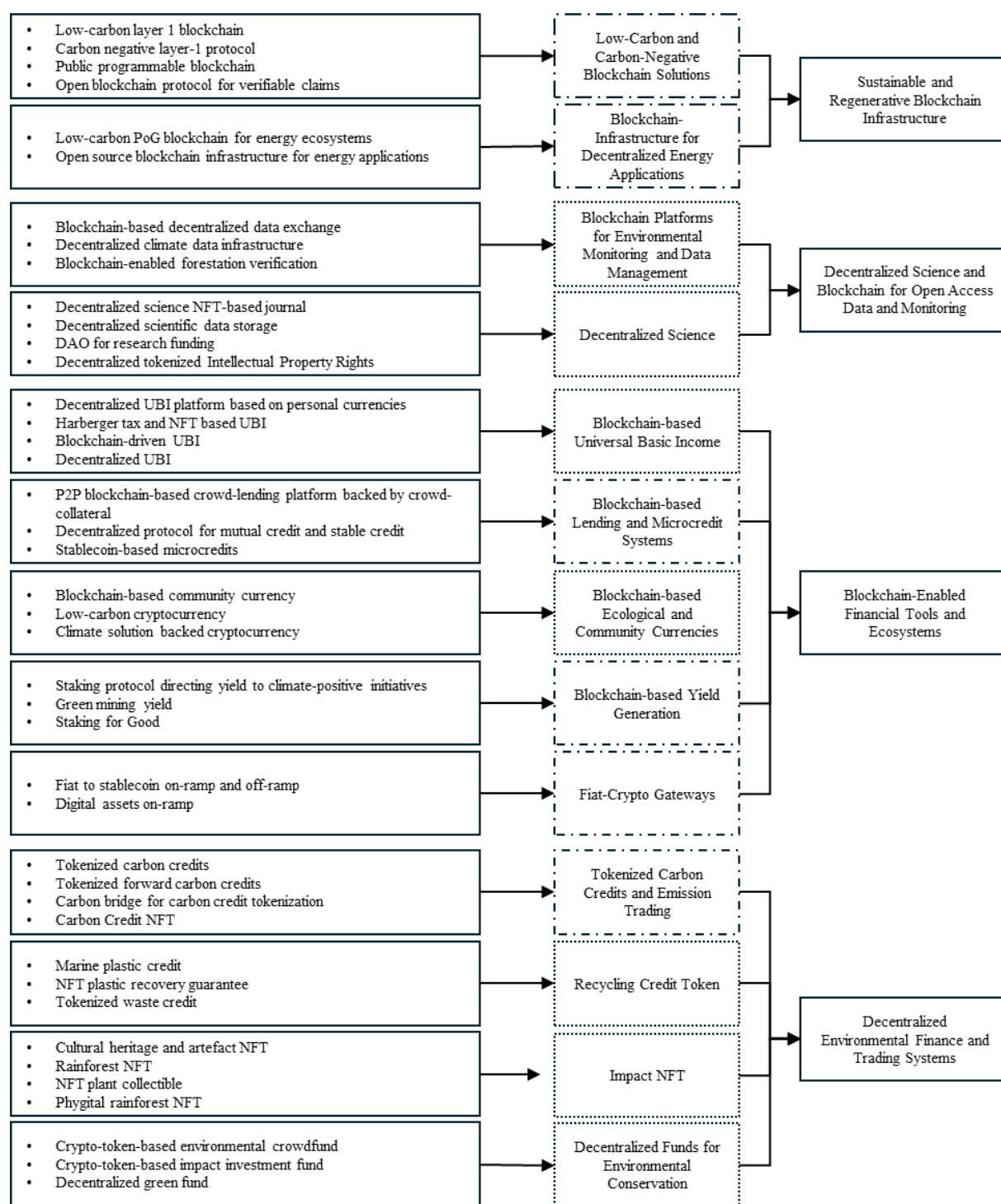
In addition, the data was initially reduced by using the technique of inductive open coding. This involved identifying specific blockchain-based applications and assigning codes accordingly, following the approach outlined by Corbin and Strauss (1990) and Vollstedt and Rezat (2019). This initial process laid the groundwork for identifying patterns and similarities (Corbin and Strauss 1990), which are essential for creating a thorough taxonomy in the given study. The inherent flexibility and openness of the open coding method allow for the emergence of new concepts from the data (Charmaz 2006; Corbin and Strauss 1990; Elliott 2018), facilitating the exploration of scientifically and practically unexplored applications within the ReFi sector.

During the initial open coding phase, a total of 186 codes were assigned. Following a careful refinement and recoding process, based on the experience of the first coding cycle (Saldana 2021), the number of codes was reduced to 97 and 68 codes in a subsequent iterative stages. This falls within the anticipated range of 30-300 final codes for qualitative, open-coding studies, as noted by Friese (2019), MacQueen et al. (1998) and Saldana (2021).

During the subsequent analysis, the text-based first order codes were further refined through axial coding. Here, the codes were summarized in a more abstract manner by establishing connections and categorizing them according to shared relationships (Corbin and Strauss 1990; Kendall 1999). This process allows for the creation of second-order topics or, in this particular context, application groups. Adhering further to the design principles set forth by Gioia et al. (2013) and Magnani and Gioia (2023), the second-order themes were derived through a systematic combination of an inductive and abductive approach. By using this combined approach, the second-order themes identified were then compared with the existing literature to systematically combine the final second-order themes (Magnani and Gioia 2023). After identifying the second-order themes, an in-depth review of the data was conducted to discover whether there were any open categories that were not fully explored before (Corbin and Strauss 1990; Vollstedt and Rezat 2019). Nevertheless, no further second-order themes were identified, suggesting that the point of theoretical saturation has been achieved (Kendall 1999; Saunders et al. 2018). At last, the second-order themes were classified into broader, consolidated dimensions. Appendix 1 presents a summary of the data sample that was evaluated. This data sample serves as the foundation for the data structure illustrated in Figure 5.

4 Findings

In the following chapter, a comprehensive summary is presented, outlining the 21 blockchain application groups and eight overarching dimensions in ReFi that have been obtained from the initial data set. The data structure obtained using the Gioia methodology presented in Figure 5 serves as the foundation for the taxonomy created in Figure 6.



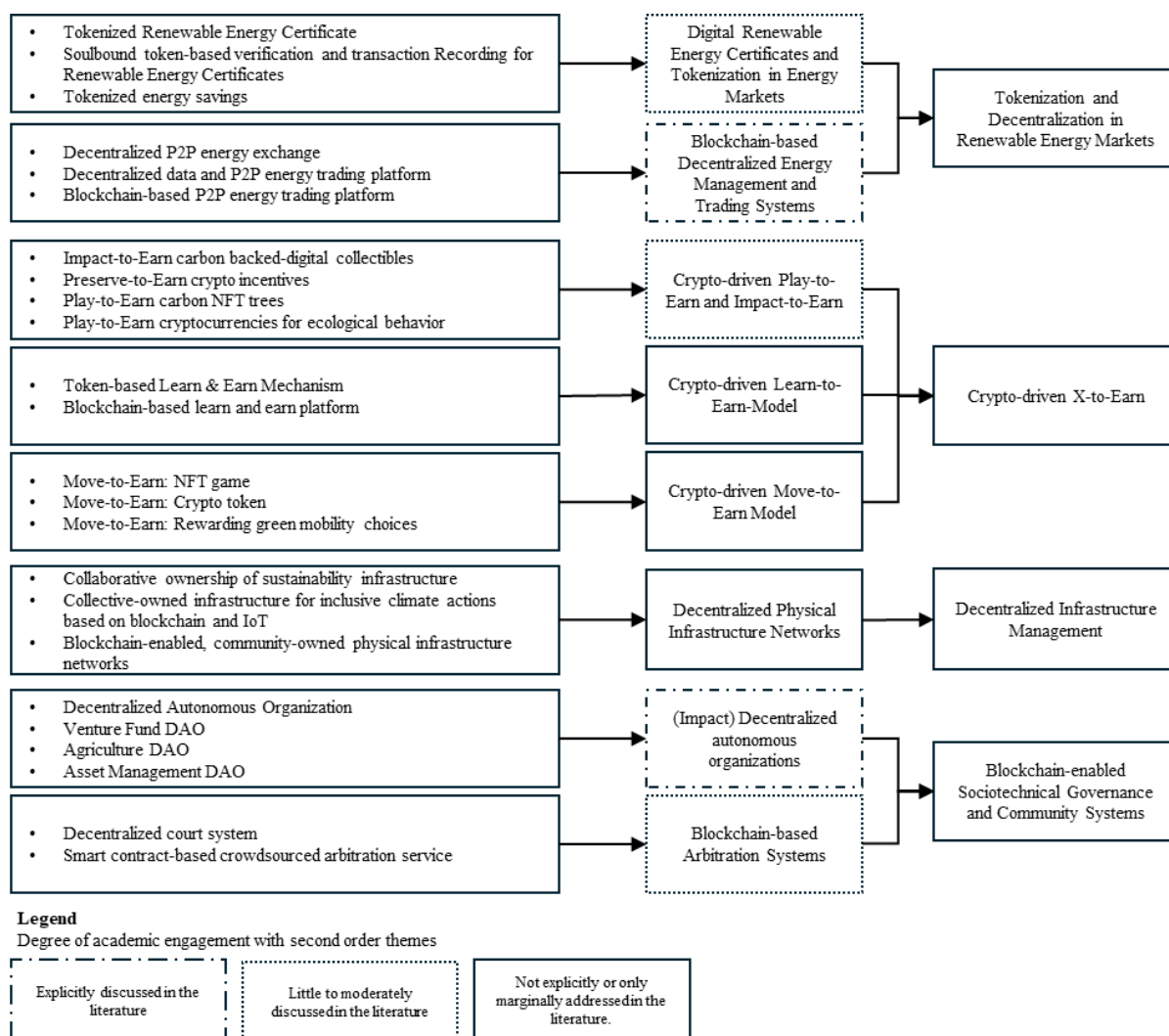


Figure 5: Data structure underlying the study
Source: Own presentation based on Gioia et al. (2013)

4.1 Sustainable and Regenerative Blockchain Infrastructure

Low-Carbon and Carbon-Negative Blockchain Solutions

The first application scenario within the extracted ReFi-DAO dataset is the provision and development of sustainable, open-source, and decentralized infrastructures using Blockchain Technology. As an example, the IXO protocol establishes a novel open-source standard for verifiable impact claims (Conway et al. 2021). This is built upon decentralized web standards, decentralized identifiers (DiD) and linked data. The open protocol serves as the basis for developing NFT impact tokens, community currencies, impact verification apps, and programmable capital such as impact, innovation, or insurance bonds (Conway et al. 2021). VeChain (2023), EverGreenCoin (2019), and Celo (2024) specifically prioritize the development of a low-carbon blockchain. VeChain (2023) as created VeChain Thor, a public enterprise platform that operates on a proof-of-authority consensus mechanism. This platform integrates Web3 features and is designed to help companies and governments achieve their sustainable development goals (SDGs) (VeChain 2023). On the other hand, EvergreenCoin utilizes a low-carbon proof-of-stake (PoS) blockchain to mine its own environmentally friendly cryptocurrency (EverGreenCoin 2019). Celo is creating an open cryptographic protocol that is compatible with the Ethereum Virtual Machine (EVM) and has a negative carbon footprint (Celo 2020, 2024). This protocol allows for the creation of decentralized payment methods, such as Stable Coins, and mobile decentralized finance (DeFi) applications (Celo 2020, 2024). In the future, Celo will undergo a transition from being a layer 1 protocol to being an Ethereum layer 2 protocol (Celo 2024). Furthermore, DAO IPCI (DAO IPCI 2018) is establishing a publicly accessible blockchain framework that relies on smart contracts. This infrastructure aims to facilitate transactions related to carbon, green bonds, and digital renewable energy certificates (dRECs), while keeping transaction fees at a minimum. Additionally, DAO IPCI has created its own ecosystem token which serves as a medium of exchange for tokens associated with natural capital (DAO IPCI 2018).

Blockchain-Infrastructure for Decentralized Energy Applications

Upon deeper examination of low carbon and carbon negative blockchain infrastructure, it is apparent there are several infrastructure solutions particularly designed for the energy industry. This entails developing a customized blockchain infrastructure specifically designed for the energy industry, with an emphasis on sustainability, decentralized operations, and effective energy market processes. This infrastructure is illustrated by solutions like Rowan Energy (RowanEnergy 2023), which utilizes a Proof-of-Generation (PoG) consensus and promotes low carbon blockchain technology. This is marked by a greater emphasis on energy efficiency, as transactions are only verified if the energy used can be verified as generated from renewable sources (RowanEnergy 2023). In addition, Energy Web (Energy Web Foundation 2019) has created a public Proof-of-Authority (PoA) blockchain that incorporates self-sovereign DiD, is compatible with smart contracts, and allows for proofs of data and events. This blockchain seamlessly integrates into a decentralized operating system, empowering the establishment of bottom-up energy markets. This system is designed to support the decentralization of the energy sector and provide greater flexibility and ownership of energy sources for customers (Energy Web Foundation 2019). Powerledger (2023) is focused on expanding sustainable and decentralized energy initiatives, like energy marketplaces and peer-to-peer energy trading. They utilize a Solana code-based, Proof-of-History (PoH) and Proof-of-Stake (PoS) public blockchain, along with an Ethereum-based token, to promote the democratization of the energy market in an energy-efficient manner (Powerledger 2023).

4.2 Decentralized Science and Blockchain for Open Access Data and Monitoring

Blockchain Platforms for Environmental Monitoring and Data Management

Another set of applications includes advancing open, inclusive, and decentralized access to data, along with implementing transparent and traceable MRV mechanisms. Blockchain-based open protocols, like the Open Forest Protocol (Open Forest Protocol 2023), utilize a token-based crypto-economic incentive and management system. These protocols rely on a collective data verification model to allow unrestricted access to standardized data. This, in turn, aims to facilitate scaling and funding for global reforestation initiatives (Open Forest Protocol 2023). Furthermore, Hara (2019) provides a decentralized marketplace model on the Ethereum platform. This model facilitates the sharing of agricultural data from various sources such as IoT, satellites, and data collected by farmers. Hence, it supports funding and incentivizes data collection and verification through a distinctive ecosystem token. The objective is to enhance

the accessibility and democratization of agricultural data (Hara 2019). In a similar vein, dClimate (2021) has developed a decentralized system and network for climate data. This system utilizes a four-layer model consisting of governance, oracles, blockchain, and data storage layer and intends to facilitate the sourcing, provisioning, storage, and incentivization of high-quality climate data (dClimate 2021). In addition, Sovereign Nature offers a decentralized ecological economics protocol that allows for the creation of smart contract-based ecolinked assets (Leiter et al. 2023). These assets combine physical or digital goods with ERC-721 data tokens and asset decentralized identifiers (Leiter et al. 2023).

Decentralized Science

Within this second order theme, there are numerous applications that utilize blockchain technology to promote open and democratized data and science. These applications align with the principles of decentralized science, as described by Ding et al. (2022) and Friedman et al. (2022). Among them are the use of Web3 technology, the creation of a decentralized polycentric governance structure, and the tokenization of datasets and intellectual property. Further, this framework may consist of a DAO framework, a bottom-up methodology, decentralized financing mechanisms, and unrestricted accessibility to data (Ding et al. 2022; Friedman et al. 2022).

One example is VitaDAO, a decentralized and autonomous organization operating on the Ethereum blockchain (Golato and Kohlhaas 2021). The objective is to enhance accessibility to the procurement, finance, and administration of intellectual property and data assets in the biopharma industry by using decentralized governance, blockchain tokens, smart contracts, and crowdfunding (Golato and Kohlhaas 2021). Another example is deScier, which demonstrates the emergence of a decentralized scientific ecosystem through the implementation of a DAO governance structure, tokenized NFT publications, and IP rights, along with fungible tokens on the Ethereum and Polygon platforms. This ecosystem strives to enhance the accessibility and decentralization of knowledge and scientific resources, along with funding and publications (Freitas et al. 2023). Moreover, PlantGang aims to enhance the accessibility of plant specimens to a wide audience via the establishment of a decentralized virtual herbarium. This herbarium will be built on blockchain technology and will be reinforced by non-fungible tokens (PlantGang 2023). The sale of NFT plant specimens aims to promote community involvement and contributes to the funding of research (PlantGang 2023).

4.3 Blockchain-Enabled Financial Tools and Ecosystems

Blockchain-based Universal Basic Income

Further, data analysis has uncovered a variety of decentralized and blockchain-based approaches to implementing universal basic income (UBI). For instance, Circles strives to establish a decentralized monetary system that prioritizes individuals and is supported by personal and complementary cryptocurrency (Circles UBI 2023). This currency is regularly generated and distributed as a universal basic income to users, deriving its value from trust (Circles UBI 2023). The GoodDollar is a decentralized DAO-governed protocol that utilizes its own scalable fungible crypto token to provide financing and smart-contract-based value distribution of a universal basic income to individuals who are financially underserved (Assia et al. 2022). The UBI is funded through DeFi concepts like yield farming, liquidity mining, and Staking for Good (Assia et al. 2022). ImpactMarket is a decentralized social finance protocol that distributes donations and crowd-sourced funds to underprivileged communities using Celo Stablecoins (Zapelão and Ajit 2023). In the digital game "The Space", NFTs are readily accessible for purchase through a unique dual system that combines partial common ownership with a Harberger tax. The tax revenue generated is subsequently distributed to all NFT owners as a form of UBI (Matters Lab 2022).

Blockchain-based Lending and Microcredit Systems

Another topic that arises from the raw data and the initial codes is the concept of credit and microcredit models that are based on blockchain technology and decentralized networks, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden. 5**. This theme can be connected to the concept of a token-based mutual credit network protocol from Stable Credit (2023). The protocol incorporates oracles, an assurance pool, a reserve currency to support the network currency, and ERC20-based credit lines to eliminate the need for external capital (Stable Credit 2023). Furthermore, EthicHubs provides a financial inclusion tool that enables farmers without access to conventional banking services to acquire low-interest microloans. (EthicHub 2023). This is achieved through the utilization of blockchain technology, smart contracts, and NFT bonds on a crowdlending platform. The loans are backed by crowdcollaterals acquired through crypto token staking (EthicHub 2023). In a similar vein, the wallet function of Impact-Market Libera Wallet dApp provides microcredit in the form of Celo Dollar Stablecoins to entrepreneurial networks that lack access to traditional banking services (Zapelão and Ajit 2023).

Blockchain-based Ecological and Community Currencies

During the investigation of blockchain applications in the ReFi DAO dataset, numerous innovative strategies were discovered that pertain to the advancement of cryptocurrency, including nature-backed (Single.Earth 2022), green (EverGreenCoin 2019), and community currencies (Circles UBI 2023; Grassroots Economics 2024). Single.Earth has pioneered a financial system underpinned by a nature-backed currency that incentivizes the conservation of forested areas (Single.Earth 2022). This system leverages a blockchain token, minted based on the ecological integrity of digitally monitored forest areas, rewarding landowners for preservation efforts with a designated utility token (Single.Earth 2022). Similarly, Solarpunk DAO has introduced an ecological cryptocurrency that operates on the Polygon blockchain (Solarpunk DAO 2023). This currency serves as both a financial and exchange medium, supported by a diverse array of climate projects, but it is not tied to any specific natural asset (Solarpunk DAO 2023). In a parallel initiative, Sintrop aims to establish a decentralized network of individuals unified by a global regeneration principles, facilitated by blockchain technology (Ravagnani 2023). This network encourages and rewards regenerative ecosystem activities through a proprietary Ethereum-based utility token known as the Regeneration Credit Token (Ravagnani 2023). Furthermore, Seeds by Hypha has developed a hybrid utility and cryptocurrency token that initially rewards cultural and ecological regeneration (Seeds 2021). This token forms the basis of an ecosystem that underpins the envisioned financial and governance systems of a decentralized citizen network (Seeds 2021). Additionally, Circles (Circles UBI 2023) has introduced a people-powered currency for its unconditional income program, and Grassroots Economics (2024) provides an open-source software stack that enables the creation of financial instruments in form of vouchers. These blockchain-based vouchers might function as mediums of exchange and digital community-run inclusion currencies (Grassroots Economics 2024). Furthermore, moving away from the focus on nature and climate solutions, EverGreenCoin has been created as a sustainable cryptocurrency with low carbon emissions. It can be used for various purposes such as holding, staking, charitable activities, and mining rewards. (EverGreenCoin 2019).

Blockchain-based Yield Generation

Utilizing blockchain technology, various methods like staking, mining, yield farming, and specialized investment strategies have emerged as innovative ways to generate financial returns from user investments (Xu and Feng 2023). A notable example is Sunrise Stake, which is developing a staking protocol that leverages the yields generated by Solana staking to support projects with a positive impact on the climate (Sunrise Stake 2024). In particular, the funds are utilized to purchase carbon credit tokens from Toucan and remove them from circulation (Sunrise Stake 2024). EverGreenCoin adopts a similar strategy by utilizing the staking of its native cryptocurrency for the purpose of "staking for charity" (EverGreenCoin 2019). Further, GoodDollar aims to introduce the "staking for good" concept, a market-driven model that does not rely on traditional donations. By utilizing decentralized third-party financial protocols, individuals have the opportunity to generate returns that are in line with market rates while keeping risks to a minimum. In addition, this approach is essential in providing a universal basic income to individuals who are financially underserved (Assia et al. 2022). Mintera (2023) likewise provides a passive income product focused on green mining, distributing yields in the form of stablecoins (Mintera 2023). Furthermore, PieDAO aims to make wealth management more inclusive and accessible by utilizing a DAO-based, tokenized, and automated approach (PieDAO 2021). This allows a broader range of individuals to benefit from investment strategies (PieDAO 2021).

Fiat-Crypto Gateways

HaloFi aims to enhance the accessibility and inclusivity of DeFi by offering a platform that combines a gamified savings application with StableCoins (HaloFi Hub 2024). The objective is to guarantee the accessibility of DeFi to a diverse group of persons, particularly those residing in areas with substantial financial instability (HaloFi Hub 2024). Similarly, Kotani Pay provides a payment platform that is explicitly created to facilitate the transition from traditional currencies to stablecoins. It also enables local payment channels in Africa, hence increasing the accessibility of decentralized finance and stablecoins (Kotani Pay 2023).

4.4 Decentralized Environmental Finance and Trading Systems

Tokenized Carbon Credits and Emission Trading

The tokenization of carbon certificates is a significant application within the data set being investigated. There are several methods available for the process of tokenizing carbon certificates. This includes the choice of blockchain platform, the type of token used (such as ERC20 or ERC-721), the characteristics of the resulting token (whether it is fungible or non-fungible), the method used to measure carbon capture (Sorensen 2023) and the standards used to back the tokenized certificates (such as Verra, Redd+ ,or Gold Standard). In addition, the tokenization process may include a unidirectional or bidirectional bridge, and there may also be the use of carbon pools to enhance liquidity.

The analysis reveals that multiple blockchain platforms, including Ethereum (Adaime 2020), Polygon (C3 2023; Nori 2024; Toucan 2024), Celo (Flowcarbon 2023; Thallo 2022; Toucan 2024), and Algorand (Carbon Credit Technology 2022), are utilized for the tokenization or bridging and trading of carbon credits. Furthermore, there are many approaches to carbon credit tokenization or on-chain bridging. Thallo (2022), Flowcarbon (2023), Toucan (2024) use two-way bridges to enable the transfer of conventional carbon certificates to a host blockchain and vice versa. However, C3 (C3 2023) utilizes a unidirectional bridge to avoid any occurrences of double counting. Thallo Retirement use NFTs for the same reasons (Thallo 2022). Furthermore, there are differences in the token standards utilized: Companies such as Moss (Adaime 2020), Flowcarbon (Flowcarbon 2023), Solid World (Solid World 2023), and Thallo (Thallo 2022) use the interchangeable and transferable ERC20 token standard for the process of carbon credit tokenization. However, C3 and Toucan use a combination of the non-fungible ERC-721 and the fungible ERC20 standard, creating a hybrid form (C3 2023; Toucan 2024). During this phase, carbon removal or avoidance projects are first migrated to the blockchain as a group of NFTs and then divided into smaller units of ERC20 tokens, which enabling carbon credit pooling (Toucan 2024). Nori (Nori 2024), Brokoli Network (Brokoli Network 2023) and Carbon0.fi (Carb0n.fi 2022) employ a distinct non-fungible standard to mint Carbon Removal NFTs. Furthermore, C3, FlowCarbon, and Toucan use carbon pools to augment the liquidity and trading of their tokenized or bridged carbon certificates (C3 2023; Flowcarbon 2023; Toucan 2024). C3 offers distinct carbon pools for different certificates (C3 2023), whereas FlowCarbon use bundling to aggregate GCO2 tokens (Flowcarbon 2023). Toucan enhances liquidity by leveraging different carbon pools and offering specific contracts such as NCT (Nature Carbon Tonne) and BCT (Base Carbon Tonne) (Toucan 2024). Overall, all approaches

aim to improve transparency, traceability, and accessibility in the (voluntary) carbon credit market.

Recycling Credit Token

The Open Earth Foundation introduce the concept of a marine plastics credit, which can be viewed as a form of restoration credit within the broader framework of marine ecosystem credits (Filippi et al. 2022). The MRV and distributed ledger-based plastic credits aim to encourage initiatives that remove one ton of plastic from the ocean (Filippi et al. 2022). In a similar vein, Plastiks (Nozama 2023) has developed an NFT marketplace for plastic recovery guarantees utilizing Celo's blockchain system and smart contracts. The plastic recovery certificates utilize the ERC721 and ERC1155 token standards to represent a comprehensive certificate. This certificate encompasses vital information such as the amount and whereabouts of the collected plastic, the identity of the collector, and an invoice from the recycler (Nozama 2023). In addition, Oxygen-Chain has implemented a “healing credit” as part of its decentralized protocol for recycling & treatment services (Colvin et al. 2021). This credit represents the amount of recycled or treated trash, measured in cubic meters or tonnage (Colvin et al. 2021). This is recognized with Oxygen, a distinctive utility token that enables token staking as well as the incentivization of recycling and waste treatment operations. Furthermore, Litter Token adopts a strategy that encourages individuals to collect and recycle waste by offering financial incentives through its own cryptocurrency token, called Litter (Litter Token 2022). The token is employed on Polygon/Ethereum and operates on a crowd-funding model. A token is granted once photographic evidence is provided of the collection of 25 pieces of waste (Litter Token 2022).

Impact NFT

Based on the studied data, it is readily apparent that blockchain technology aims to have a substantial role in the development of impact investment solutions. An intriguing application is the implementation of impact tokens, as defined by Uzsoki and Guerdat (2019), as digital assets that possess distinct and measurable effect and contribute to the advancement of the Sustainable SDGs). Several projects have surfaced that focus on non-fungible tokens and aim to promote ecological conservation and cultural heritage. Examples of these are NFTs that showcase cultural heritage or artifacts, representing tangible or intangible cultural assets like traditional ceremonies, musical expressions, craft know-how, or works of art (MetAmazonia 2023; Quantum Temple 2023). Further, projects also include ecological NFTs that represent endangered species, specific plants, wild animals, trees, entire rainforest areas, or water (Carbon Collectible NFTs 2023; Endangered Tokens 2022; GainForest Association 2022; MetaTrees 2022; PlantGang 2023). This collection of NFTs aims to serve as a means of encouraging economic participation and raising funds for the protection of the environment and cultural heritage, ultimately aiming to support the development and resilience of local communities, minimize poverty-driven deforestation and conservation efforts (Carbon Collectible NFTs 2023; Endangered Tokens 2022; GainForest Association 2022; MetAmazonia 2023; Quantum Temple 2023). Essentially, the NFT impact financing system operates through two channels: One option is to tokenize natural assets and use the proceeds to support ecological conservation or social projects. Alternatively, a donation can be made, such as in the form of a cryptocurrency, and then rewarded with an NFT as “Proof-of-Impact”. Both forms of NFTs can be supported by impact NFTs that utilize environmental data from technologies like drones, satellites, and wildlife cameras (GainForest Association 2022; ImpactScope 2024; MetAmazonia 2023). By utilizing cutting-edge technology, it becomes feasible to create “dynamic Proof-of-Impact NFTs” (dNFTs). These dNFTs allow for the real-time and tamper-proof measurement and storage of impact, enabling in the development of a financial instrument focused on impact outcomes (ImpactScope 2024).

Decentralized Funds for Environmental Conservation

Decentralized green funds or impact funds represent an innovative financing approach that merges technology with environmental preservation, with the goal of attracting financial capital for sustainable activities. Decentralized fund protocols can be considered as the intersection connecting financial instruments, digital currencies, and trading platforms (Westerberg 2023). Utilizing blockchain technology and smart contracts, the administration and distribution of funds are automated, effectively eliminating the necessity for intermediaries. Smart contracts allow for the automation of transactions and ensure that funds are only released once specific conditions or goals are met. An illustration of this is GainForest (2022), a platform that motivates local communities to preserve ecosystems by providing automatic rewards. Furthermore, stakeholders receive compensation through a system of dynamic, non-fungible tokens. Aquari (Aquari Foundation 2021), a token-based crowdfunding platform for the Decentralized Environmental Protection Fund, utilizes a similar method that provides financial incentives for token holders to stake Aquari tokens, thereby encouraging environmental fundraising and creating a decentralized fund (Aquari Foundation 2021). In a similar vein, Gaia ReFi (Gaia ReFi 2023) enables cryptocurrency users to deposit their cryptocurrency holdings in Gaia-Token, establishing an impact investment fund that employs the principles of decentralized finance to finance climate crisis solutions. Investors contribute to a fund by trading assets for \$GAIA tokens (Gaia ReFi 2023). The funds are thereafter allocated to environmental activities that have a substantial impact. These ventures not only provide financial incentives, but also envision to have positive external impacts.

4.5 Tokenization and Decentralization in Renewable Energy Markets

Digital Renewable Energy Certificates and Tokenization in Energy Markets

Another field of application that arises from the data is the tokenization of market-based instruments in the energy sector, including renewable energy certificates (RECs) (Zuo 2022). These certificates validate the generation of a megawatt hour (MWh) of electricity from renewable sources (Zuo 2022) and serve as incentives in the private sector to support the growth of renewable energy (Welsh and Bakhshi 2023). By leveraging a technologies including blockchain, AI, and IoT, these certificates are transformed into digital assets that can be tokenized and traded (Arkreen 2024; Welsh and Bakhshi 2023). These tokens can be classified either as fungible (Welsh and Bakhshi 2023) or non-fungible digital representation (Greeneum 2022; RowanEnergy 2023). In addition, providers may transfer conventional REC certificates

to the blockchain via on-chain bridging (Arkreen 2024). In addition, SoulBound tokens can represent retired REC certificates (Welsh and Bakhshi 2023). Furthermore, SoulBound tokens have the capability to symbolize REC certificates that have been withdrawn, as shown by Reneum Welsh and Bakhshi (2023). These tokens serve as both a representation of the entire quantity of MWh funded by a particular customer and as an immutable digital proof of purchase and liquidation (Welsh and Bakhshi 2023). By leveraging blockchain technology, the authenticity and traceability of the RECs (Greeneum 2022; RowanEnergy 2023) and their corresponding SoulBound tokens are guaranteed (Welsh and Bakhshi 2023). Efforce enables the process of converting Renewable Energy Certificates into digital form, as well as the transformation of energy savings into tokens utilizing smart contracts and NFTs (Eforce 2023). Each energy-saving project is categorized by Efforce into a certain quantity of tradable non-fungible tokens (NFTs) throughout this procedure. These non-fungible tokens represent involvement in an energy-saving project and are funded through crowdsourcing. Moreover, individuals who possess NFT tokens can potentially earn rewards through smart contracts by participating in energy-saving initiatives (Eforce 2023).

Blockchain-based Decentralized Energy Management and Trading Systems

Another application of blockchain technology in the ReFi sector involves around the transition from centralized to decentralized platforms and marketplaces for energy trading. Grid Singularity, for instance, facilitates peer-to-peer energy trading and the establishment of inclusive and democratic decentralized social energy networks that can benefit from multi-stakeholder energy exchange, direct energy exchange, and potentially higher efficiency (Grid Singularity 2024). In a similar vein, SunContract, Rowan and Greeneum make use of blockchain technology. Suncontract utilizes blockchain technology and tokenization to establish a peer-to-peer trading platform that effortlessly links energy producers and consumers (SunContract 2017). The platform utilizes smart contracts, a decentralized energy pool, and a distinctive Ethereum-based ecosystem token. This token serves a dual purpose, allowing users to make payments and trade energy. In this model, the blockchain is essential for ensuring transparency, security, and traceability for all transactions. It also supports the advancement of digitalization in electricity trading, enhancing its flexibility, democratization, and user-centric approach (SunContract 2017). Similarly, Greeneum is working on a decentralized data and energy marketplace that incorporates blockchain, IoT, and AI technologies (Greeneum 2022). This marketplace facilitates the connection between producers, consumers, and investors, allowing them to engage in immediate peer-to-peer energy and data transactions. The

blockchain is utilized for the authentication and storage of data, while also supporting a Ethereum-based token that forms the foundation of the payment system and the incentivization of green energy production (Greeneum 2022). Furthermore, Rowan Energy developed a permissioned proof-of-generation blockchain-based platform for renewable energy peer-to-peer trading, which includes tokenization for the generation of ERC-721-based carbon offset and RECs (RowanEnergy 2023). Additionally, Rowan has introduced the Rowan Coin, a unique incentive and ecosystem token for promoting green energy production (RowanEnergy 2023).

4.6 Crypto-driven X-to-Earn

The concept of decentralized applications or business models like "Play-to-Earn" and its variations, such as "Impact-to-Earn," "Measure-to-Earn", "Plant-to-Earn", "Preserve-to-Earn" "Learn-to-Earn," or "Move-to-Earn," described in subsequent chapters, incorporates blockchain technology, financial mechanisms, incentive systems, and interactive gaming elements (Bansal et al. 2022; Taulli 2022; Yu et al. 2022). These elements provide users with rewards for their gameplay and specific interactions using digital assets like NFTs or fungible tokens (Thomason 2021; Yu et al. 2022)

Crypto-driven Play-to-Earn and Impact-to-Earn

The analysis of the raw data reveals a shift in the traditional play-to-earn model towards emerging models like "Impact-to-Earn", "Plant-to-Earn", "Preserve-to-Earn" and other play-to-earn models that specifically focus on environmental actions. These models leverage blockchain technology. Specifically, tokenization is employed to encourage individuals to engage in environmentally conscious behaviour and promote awareness of ecological concerns. Furthermore, these models encourage and reward active participation within the relevant ecosystem. There are various initiatives that promote sustainability and incentivize individuals to take eco-friendly actions. For instance, Ecosapiens offers dynamically evolving NFTs as a reward for offsetting carbon emissions (Neelakanti 2023). Another example is ZeLoop, a platform that operates within the circular economy and encourages users to collect plastic bottles by providing rewards in the form of their own Ethereum-based ecosystem token (ZeLoop 2020). Additionally, Future Quest offers incentives to users who take action on climate change by utilizing its own utility token (Future Quest n.d.). Arkgreen, on the other hand, encourages users to offset Bitcoin emissions by providing corresponding NFT rewards (Arkreen 2024). Meanwhile, Brokoli enables users to make their impact more tangible and

monetize their NFTs (Brokoli Network 2023). In addition, Endangered Tokens encourages users to invest in tokenized NFT endangered species in the future by introducing a dedicated utility and currency token (Endangered Tokens 2022). MetaTrees is introducing a "Plant-to-Earn" model in a blockchain game-world. This model incentivizes players to conserve real-world natural resources by rewarding them with in-game NFTs and tokens. These rewards can be utilized for various purposes such as item purchases, staking, holding, and playing (MetaTrees 2022). GainForest employs the same approach for implementing the "Measure-to-Earn" concept. This methodology provides incentives to local data collectors for their grassroots MRV efforts. As a kind of compensation, they are rewarded with Solana tokens or stablecoins (GainForest 2022).

Crypto-driven Learn-to-Earn-Model

The second order topic of "Cryptocurrency-based Learn-to-Earn-Model" explores the intersection of crypto tokens and education, aiming to establish an innovative economic model that incentivizes learners for their dedication and time invested in acquiring knowledge (Wong and Huen 2023). An incentive system based on tokens is utilized by ImpactMarket to support underbanked communities, women, and children who successfully complete Lean&Earn modules on relevant Web3 subjects (Zapelão and Ajit 2023). As a result, they receive compensation in the form of the ecosystem token \$PACT, which aims to enhance and incentivize their financial literacy (Zapelão and Ajit 2023). Ecosapiens is exploring the creation of a comparable mechanism with the goal of educating individuals about the environment and providing incentives in the form of carbon credits or NFTs (Neelakanti 2023).

Crypto-driven Move-to-Earn Model

Another concept that can be derived from raw data is "Move-To-Earn". The concept incorporates blockchain technology, wearables, interactive games, and financial components to motivate encourage physical activities like walking, running, or cycling (Bansal et al. 2022; Yu et al. 2022). Blockchain-based gamified fitness ecosystems like Stepn (STEPN 2024), OliveX (OliveX 2022), Calo Metaverse (Calo 2023), Genopets (Genopets 2023) or Meta Gym (MetaGym 2022) bring together game and social elements, along with their own unique blockchain-based ecosystem tokens and NFTs. Their objective is to inspire users to participate in increased physical activity and offer them digital assets such as fungible tokens and NFTs as incentives. These can also be used to obtain in-game items, NFTs, or exchanged for monetary value, depending on the application (Calo 2023; Genopets 2023; MetaGym 2022; OliveX 2022;

STEPN 2024). Moreover, certain applications utilize NFTs as a form of membership pass, granting users access to the movement incentive scheme. In essence, the Web3 applications are utilized to encourage a more healthy way of living, generate income passively, and provide an incentive to utilize the Move-to-Earn application (Calo 2023; MetaGym 2022; OliveX 2022; STEPN 2024). Additionally, Wheelcoin offers a modified Move-Earn approach that incentivizes the adoption of eco-friendly transportation options. Users are rewarded with crypto tokens for choosing green mobility alternatives and reducing their CO2 emissions (WheelCoin 2023).

4.7 Decentralized Physical Infrastructure Networks

Decentralized Physical Infrastructure Networks (DePINs) represent an emerging concept in the blockchain ecosystem and niche topic in the ReFi-DAO dataset, focusing on integrating distributed ledger technology with physical infrastructure projects (Ballandies et al. 2023). These networks utilize distributed ledger system like blockchain to create decentralized systems for various infrastructural developments, often with a focus on renewable and sustainable resources (Ballandies et al. 2023). DePINs aim to facilitate seamless connectivity, improved asset management, and enhanced economic models through cryptoeconomics, ultimately leading to more resilient and inclusive infrastructure systems (Ballandies et al. 2023). Both Arkreen (2024) and HomeDAO (2023) take this approach. While Arkgreen aims to build a decentralized network for distributed, data-driven integration of renewable energy sources and facilitate their connection and monetization to tokenize green energy resources to achieve wider and inclusive access to renewable energy and an emission-free environment (Arkreen 2024). Home DAO, in turn, focuses on creating a decentralized network that enables individuals and communities to manage meaningful renewable infrastructure assets in a common ownership model. The tangible physical infrastructure, such as clean energy, water infrastructure, or sustainable housing projects, contributes to the ecosystem's native utility token. This token is utilized to finance community-owned assets and governance in the DAO, resulting in a self-sustaining cycle known as the DePIN network flywheel (HomeDAO 2023).

4.8 Blockchain-enabled Sociotechnical Governance and Community Systems

Decentralized Autonomous Organizations

Further, analysis shows that 42 of the 88 companies use or plan to use DAOs or semi-automated and decentralized governance structures to manage and govern their organizations, protocols and applications. Within this context, 23 organizations have implemented their own governance tokens based on blockchain technology, allowing for decentralized decision-making processes that enable community centric engagement. The use cases for DAOs are diverse: Kokonut DAO (Kokonut Network 2024) aims to finance, manage and organize real coconut farms through blockchain governance. Similarly, Home DAO aims to finance community ownership of renewable infrastructure, while OASA aims to create physical, regenerative habitats through DAO governance structures and its own crypto token, making the transition from ownership to stewardship. In addition, ReversClimateChange (Alexander 2023) and AeraForce (Aera Force 2024) are developing liquidity services and decentralized venture funds that finance ReFi projects based on community decisions. VitaDAO uses a DAO to fund research and manages scientific artifacts on DAO-based governance (Golato and Kohlhaas 2021). This pattern illustrates that numerous organizations are using decentralized (blockchain-based) governance mechanisms not only to make technical protocol decisions, but also to promote decentralization, democratization, management and stewardship of shared resources through DeFi governance principles and blockchain technology.

Blockchain-based Arbitration Systems

Another significant use case that emerges from the data analysis is the development of private, decentralized, crowdfunded, and blockchain-based dispute resolution systems. An interesting example is Kleros (Lesaeye et al. 2019), a decentralized application built on the Ethereum platform that focuses on resolving disputes in the digital economy. Created as an opt-in court system, it utilizes smart contracts to choose arbitrators and a token-based staking system to ensure impartial rulings. Kleros strives to offer a more accessible, cost-effective, swift, and dependable means of accessing arbitration (Lesaeye et al. 2019).

5 Discussion

The aim of this study was to create a tangible taxonomy of blockchain applications in the field of Regenerative Finance, an area of research that has not yet been extensively explored. In order to gain an in-depth understanding of the Regenerative Finance ecosystem from a market-based perspective, a qualitative and exploratory research approach utilizing the Gioia methodology was applied. Figure 6 illustrates the identification of 21 specific blockchain application categories and eight overarching dimensions associated with the ReFi ecosystem according to the current analysis. The results illustrate that both blockchain applications and the ReFi ecosystem are significantly more heterogeneous than described by Schletz et al. 2023 and go far beyond the mere tokenization of carbon credit tokens and ecosystem services. Furthermore, the study shows that using blockchain technology, the analyzed ReFi whitepapers aim for a paradigm shift that is in line with Hartley and Rennie (2022) and seeks transformative solutions in economic, social and environmental areas. The subsequent discussion responds to a call by Schletz et al. (2023) to critically examine the regenerative capacities of ReFi applications. Specifically, the section focuses on blockchain applications in the ReFi space, evaluating their sustainable, equitable, inclusive, and regenerative characteristics from a theoretical perspective to determine if they align with the imperatives envisioned by the ReFi movement as outlined in chapter two. Finally, the significance of the findings is highlighted, considering their theoretical and practical implications, and possible directions for future research are discussed.

| Regenerative Finance Ecosystem | | | |
|---|---|--|---|
| Blockchain-enabled Sociotechnical Governance and Community Systems | Decentralized Science and Blockchain for Open Access Data and Monitoring | Tokenization and Decentralization in Renewable Energy Markets | Sustainable and Regenerative Blockchain Infrastructure |
| (Impact) Decentralized Autonomous Organizations | Blockchain Platforms for Environmental Monitoring and Data Management | Digital Renewable Energy Certificates and Tokenization in Energy Markets | Low-Carbon and Carbon-Negative Blockchain Solutions |
| Blockchain-based Arbitration Systems | Decentralized Science | Blockchain-based Decentralized Energy Management and Trading Systems | Blockchain-Infrastructure for Decentralized Energy Applications |
| Blockchain-Enabled Financial Tools and Ecosystems | Decentralized Environmental Finance and Trading Systems | Crypto-driven X-to-Earn | Decentralized Infrastructure Management |
| Blockchain-based Universal Basic Income | Tokenized Carbon Credits and Emission Trading | Crypto-driven Play-to-Earn and Impact-to-Earn | Decentralized Physical Infrastructure Networks |
| Blockchain-based Lending and Microcredit Systems | Recycling Credit Token | Crypto-driven Learn-to-Earn-Model | |
| Blockchain-based Ecological and Community Currencies | Impact NFT | Crypto-driven Move-to-Earn Model | |
| Blockchain-based Yield Generation | Decentralized Funds for Environmental Conservation | | |
| Fiat-Crypto Gateways | | | |

Figure 6: Taxonomy of Blockchain Applications in Regenerative Finance

Source: Own representation

An Economic Perspective on Regenerative Finance

Blockchain technology may introduce profound shifts in traditional financial systems, establishing new paradigms for economic engagement, value creation, and ecosystem development (Abdollahi et al. 2023; Schlecht et al. 2021). Themes such as blockchain-based universal basic income and decentralized credit/microcredit systems show a departure from traditional financial frameworks and provide technology-based foundations for well-known concepts such as UBI (Papadimitropoulos and Perperidis 2024), which aim to improve and strengthen financial inclusion and empowerment (Banerjee et al. 2019). These systems aim to facilitate direct access to financial resources, bypassing traditional banking infrastructures and reducing transactional barriers (Avanzo et al. 2023; Hoque et al. 2024), which can catalyze economic revitalization at both individual and community levels (Baye 2014). Nevertheless, research conducted by Bastagli et al. (2016) and Handa et al. (2018) indicates that while the idea of UBI is already benefiting individuals in terms of income, savings, prosperity, and poverty alleviation, there is little empirical support for its direct influence on developing nations (Banerjee et al. 2019). Additionally, there is the challenge of obtaining regulatory and legislative backing, as well as an imbalanced cost-benefit ratio in a developed nation (Banerjee et al. 2019). Furthermore, past pilot initiatives, such as the unsuccessful blockchain-based UBI project in Berlin, have demonstrated that relying on blockchain technology for universal basic income is not a cure-all for economic empowerment and financial inclusion (Papadimitropoulos and Perperidis 2024). The success of such endeavors relies on the presence of a universally applicable UBI framework, which, from a technical standpoint, would be hindered by the blockchain trilemma (Low 2020; Low and Mik 2020; Papadimitropoulos and Perperidis 2024).

Improving the availability of blockchain-based yield generation platforms and crypto gateways that support DeFi activities like staking, lending, and yield farming, has significant implications for the economy and society (Abdulhakeem and Hu 2021). These technologies allow for greater access to financial services and decentralized financial markets, empowering marginalized populations to participate in financial growth (Honohan 2008). By reducing obstacles to entry and minimizing transaction costs, along with offering a blockchain wallet that functions similar to a quasi-bank account, individuals are empowered to manage their savings and conduct daily transactions, thus fostering greater financial inclusion (Darlington and K. James 2014; Holtmeier and Sandner 2019; Honohan 2008; Scott 2016). Furthermore, stablecoins provide the potential to mitigate the impact of currency fluctuation, particularly for economically marginalized communities (Murakami and Viswanath-Natraj 2021). Additionally, the

scientifically unexplored concept of "staking for good" or "staking for impact" introduces innovative methods for directing capital into social or sustainable projects, exemplified by initiatives such as GoodDollar (Assia et al. 2022). Similarly, impact NFTs can be seen as a blockchain-based investment vehicle that might improve the participation of both institutional and private investors in social and environmental projects (Uzsoki and Guerdat 2019). They provide transparent accountability and link measurable positive social and environmental impact to financial returns (Khanal 2024; Uzsoki and Guerdat 2019). However, the effectiveness of impact NFTs and tokens depends crucially on overcoming obstacles such as the introduction of consistent impact metrics and accurate MRV systems (Khanal 2024; Uzsoki and Guerdat 2019). It also requires the creation of an appropriate regulatory framework that addresses ethical and security issues. This is necessary to achieve the desired effect of democratizing the market for financial impact investments, especially for retail investors, and to improve the financing of regenerative projects.

Theoretically, the applications under discussion are designed to promote greater financial inclusion and decentralize financial services. Thus, they align with the principles of democratic and decentralized economic access, as well as the regenerative economy advocated by Fullerton (2015) and might be considered as a ReFi application. However, it should be noted that the precise and large scale economic and socio-ecological impact of these instruments, such as impact NFTs or staking for good mechanics, has yet to be proven. Similarly, the bare digitalization of well-known concepts, such as Universal Basic Income, may not necessarily lead to the desired and far-reaching ecological, economic and social effects (Papadimitropoulos and Perperidis 2024).

Emerging Economic Cryptocurrency Engagement Models

The emergence of blockchain-based models for economic engagement and incentivization, particularly those that utilize variations of the play-to-earn mechanisms such as impact-to-earn, learn-to-earn, and move-to-earn, represents a significant area of application within the ReFi ecosystem. Currently, there is no comprehensive terminology for these blockchain-based engagement models, and academic discourse has predominantly focused on play-to-earn models (Delfabbro et al. 2022; Delic and Delfabbro 2024; Vidal-Tomás 2022), while sub-engagement models such as impact-to-earn or learn-to-earn have received minimal attention. This study introduces the term "X-to-Earn" to encompass these models.

X-to-Earn models are designed not only to incentivize behavioural changes but also to redefine the mechanisms of economic value creation by linking certain action and behavioural changes to financial gains, which include, but are not limited to, cryptocurrency payouts. From the perspective of ReFi, the sub-categories of X-to-Earn such as Impact-to-Earn, Learn-to-Earn, and Move-to-Earn are particularly noteworthy. These models explicitly aim to monetize behavioural changes or actions that have social, environmental, or economic impacts. For instance, the incentivization within Move-to-Earn engagement models may be seen as regenerative. This aligns with Fullerton's (2015) perspective that regenerative systems should be viewed holistically, thus positioning societal health as a subsystem. In this context, a lack of physical activity can detrimentally affect an individual's health and, on a broader scale, the economy of a nation (Dhuli et al. 2022). While comprehensive studies on the social, economic, and environmental impacts of X-to-Earn engagement and business models are yet to be conducted, Delfabbro et al. (2022) highlight the necessity for a balance between economic opportunities and the protection of vulnerable players from potential exploitation. Therefore, careful management of these business models is essential to ensure their sustainability and the achievement of their intended (regenerative) impacts.

A Social Perspective on ReFi: Empowered Participation in Regenerative Finance

In 2008, Ostrom emphasized the success of collaborative community bottom-up governance systems in efficiently monitoring shared resources without relying on central or state intervention (Ostrom 2008; Pennington 2013). The study shows that about half of the grey literature items analyzed build on this construct and integrate or plan to integrate polycentric governance models. These models are fundamentally in line with Fullerton's (2015) principles for regenerative economies, which emphasize a vital and sustainable economic structure that takes into account decentralization and the reduction of power monopolies, as well as ReFi's own claim to contribute to more decentralization and bottom-up governance (Bryant et al. 2024). As shown in chapter four, blockchain-based DAOs and blockchain-based governance tokens are used for the technical implementation of polycentric governance systems, which in this context can serve as a modern interpretation and technological enabler of Ostrom's (2008) concepts and Fullerton's (2015) principles for minimizing the centralized governance of common pool resources and decentralized governance structures. Through the use of blockchain technology, DAOs may enable and incentivize the transparent and efficient management of community projects (Ellinger et al. 2024), offering a promising solution to the

free-rider problem that often occurs in collective action and neoliberal economic systems (Fontaine 2014; Lin 2021). In addition, according to Ellinger et al. (2024), DAOs facilitate the promotion and sustained participation of all members in decision-making and engagement, also by including token-based incentivization scheme (Ellinger et al. 2024). This form of incentivized engagement might thus promote a sense of collective responsibility and accountability and also lead to sustained participation (Ellinger et al. 2024), which in turn can be an important factor in promoting sustainability and regenerativity (Imada 2008; Macnaghten and Jacobs 1997). In addition, Ostrom (2009) highlights the importance of enforcing rules in order to establish sustainable systems. DAOs enable the establishment of rules in a flexible and inclusive way, with the execution being automated by smart contracts (Ellinger et al. 2024). This may contribute to the creation of decentralized and more equitable subsystems that align with the qualities of regenerative and sustainable community structures.

In addition to the application of polycentric governance models in DAOs, the use of Distributed Physical Infrastructure Networks is also increasing as part of a regenerative system. DePIN places economic ownership and ownership of critical economic infrastructure in the hands of communities (Ballandies et al. 2023). This is in line with Fullerton's (2015) idea of regenerative vitality, which promotes a lower concentration of wealth and power. Similarly, decentralized science applications such as VitaDAO (Golato and Kohlhaas 2021) and deScier (Freitas et al. 2023) might be considered as a components of regenerative economies. These applications aim to democratize access to scientific artifacts, funding, and intellectual property, thereby minimizing centralization in science (Ding et al. 2022). This approach aligns not only with Fullerton's (2015) fourth principle of participation empowerment but also with the third principle of regenerative vitality, fostering innovative societies that benefit from collaborative and transparent research ecosystems.

Ecological Perspective on Regenerative Finance

This study shows that the utilization of blockchain technology for the tokenization and trading of carbon credits is a crucial application within the ReFi sector. This finding is consistent with the study conducted by Schletz et al. (2023) and Hartley and Rennie (2022), which suggests that the ReFi ecosystem is predominantly focused on carbon credit tokens. Utilizing blockchain technology to tokenize carbon credits offers a promising way to address the issues often seen in conventional carbon markets, including restricted liquidity, occurrences of duplicate counting, fraudulent behavior, and a lack of transparency (Patel et al. 2020; Saraji and Borowczak 2021). The objective of this strategy is to provide a more effective market mechanism and a dependable trading environment for carbon credits. This approach advocates for the preservation and recovery of natural ecosystems by providing financial assistance for conservation and reforestation projects (Sorensen 2023). These efforts align with Fullerton's (2015) ideas of integrating the ecological design into the economy and promoting overall system well-being. Nevertheless, it is worth noting that blockchain-based carbon credits have only digitized and represented a small portion of the carbon market (Ortiz-Rodríguez et al. 2023). Consequently, the actual ecological impact they possess is uncertain (Sicilia et al. 2023). Furthermore, Böhm et al. (2012) presents a fundamental criticism of the concept of carbon markets, adopting a Marxist viewpoint on the subject. Böhm et al. (2012) contends that although these markets may facilitate innovative methods of accumulating wealth, they are unlikely to affect the fundamental dynamics of capitalism in a manner that would foster a sustainable and regenerative global economic system. This raises the question of whether the use of blockchain and other technologies, based on prevailing concepts such as carbon markets and UBI, will successfully achieve the desired ecological, economic, and social outcomes envisioned by the ReFi movement.

Moreover, the use of blockchain and other MRV technologies in the context of ecological and social projects is subject to criticism, particularly in relation to the occurrence of crypto-colonialism (Howson 2021). In order to prevent a colonialistic approach, it is crucial to guarantee that technological advancements like blockchain and MRV technologies, which encompass AI, satellites, and IoT sensors, are not forced upon the most vulnerable communities throughout the scope of carbon tracking, impact verification, and digital environmental protection (Howson 2020, 2021; Liegey and Nelson 2020). According to Howson (2021), if technologies like blockchain limit the rights of marginalized communities or maintain the historical injustice of colonial eviction, regardless of whether they are developed

collaboratively or have a positive and sustainable effect, their benefit should be challenged.

In addition, research conducted by Khalid et al. (2020) and Thompson et al. (2021) suggest that incorporating blockchain technology into two prominent ReFi use cases, namely decentralized energy infrastructure and peer-to-peer energy trading could have significant environmental benefits. This includes reducing energy consumption, minimizing electricity losses, and decreasing the emission of harmful gases (Khalid et al. 2020; Thompson et al. 2021). Additionally, Wilkinson et al. (2020) and Hua et al. (2022) demonstrate that individuals are willing to participating in P2P energy markets. This, in turn, has the potential to create an electricity market that prioritizes the needs of consumers, ultimately enhancing their socio-economic empowerment and overall well-being (Thompson et al. 2021). This can be aligned with the reduction of monopolies and the empowerment of users, which is in line with the regenerative principles of Fullerton (2015).

However, several studies have emphasized the environmental consequences of blockchain technology, including its significant energy use and the resulting carbon emissions, particularly in relation to proof-of-work consensus protocols (Badea and Mungiu-Pupazan 2021; Platt et al. 2021; Rana et al. 2019; Wendl et al. 2023). Nevertheless, this study, consistent with Sedlmeir et al. (2020) findings, acknowledges that the energy use and ecological impact of blockchain applications might differ. The analysis of the ReFi dataset reveals several instances of low-carbon and carbon-negative blockchain infrastructure. One notable example is the Rowan Proof-of-Generation blockchain, which demonstrates how blockchain technologies might be rendered more sustainable. In this system, only intelligent miners connected to renewable energy generation systems and serving as authorized nodes are permitted to validate transactions (RowanEnergy 2023).

Additional research conducted by Taherdoost (2024), Delardas and Giannos (2023), and Fu et al. (2023) has revealed that blockchain-based renewable energy certificates might have a positive environmental influence. These studies have demonstrated that RECs encourage sustainable investment practices (Han et al. 2023), incentivize investments in renewable energy (Delardas and Giannos 2023), enhance the efficiency of renewable energy systems (Taherdoost 2024), and contribute to the development of low-carbon communities (Fu et al. 2023) and sustainable commitments (Delardas and Giannos 2023). In a similar vein, recycling tokens can create incentives and rewards for individuals and companies that recycle and reduce their carbon footprint (Gibovic and Bikfalvi 2021; Gupta and Mukherjee 2022). The discourse around the ecological impact of blockchain-based ReFi applications presents a heterogenous

representation of the intended and potential actual impact of these applications. Nevertheless, it also demonstrates promise and acknowledges the existence of remaining challenges.

5.1 Implications for Theory

Based on a theoretical perspective, this study reveals four significant implications for scientific research. Initially, the taxonomy, consisting of 21 application groups and eight superordinate dimensions, offers a comprehensive understanding of the ReFi ecosystem and the largely underexplored utilization of blockchain technology in ReFi. Considering Figure 5, it is evident that certain application groups have not received much scientific attention so far, implying that the taxonomy also provides numerous emerging fields for academic research. Secondly, the taxonomy created clearly outlines and distinguishes the findings of Hartley and Rennie (2022) and aligns with the conclusion of Schletz et al. (2023) regarding the tokenization of carbon credit as a significant use case in ReFi. Nevertheless, this study highlights the diverse and varied applications beyond carbon credit tokenization, emphasizing the need for a future multidisciplinary research approach. Thirdly, upon further examination of the application groups and considering the previous discussion, it may become apparent that many blockchain applications in ReFi align with the regenerative principles proposed by Fullerton (2015), at least in theory. However, a more accurate categorization would place them most likely within the realm of sustainability, as indicated by the analysis conducted by Rani et al. (2024). This brings up the issue of the extent to which “regeneration” is truly incorporated in ReFi and highlights the viewpoint of Schletz et al. (2023) that the regenerative aspect in ReFi is by date either limited or absent. Fourthly, it is important to note that, to the best of my knowledge, the phrase “X-to-Earn” has not yet been recognized in scientific discussions. In light of this context, this research presents the term “X-to-Earn” to refer to engagement models in the crypto space that promote certain behaviours or participations by offering digital crypto-assets as rewards. The name “X-to-Earn” has a broad application and encompasses concepts like Play-to-Earn, Learn-to-Earn, and Move-to-Earn, which may also be used outside the realm of digital crypto incentives.

5.2 Managerial Implications

Exploring blockchain applications in the field of ReFi uncovers various business implications that present new opportunities for novel business models or business model innovations. However, the successful implementation and scaling of these innovative models require careful strategic considerations. Firstly, by using blockchain technology to improve transparency and traceability in environmental projects, the study highlights new opportunities for impact investment instruments such as impact NFTs and tokens. These green investment tools represent a double-edged sword. On the one hand, they enable managers to create new funding streams for regenerative projects, for instance, through the use of eco-linked assets, giving the linked assets a tangible value (Leiter et al. 2023). On the other hand, both managers and regulators have to introduce and deal with new regulatory frameworks, investor protection measures and impact assessment, as these tools might pose risks in terms of money laundering and investor fraud. Secondly, and similarly, crypto-based X-to-Earn engagement models offer the option for the creation of new business models that potentially positively impact customer value co-creation, customer engagement and incentivize anticipated behavioural changes. From a regulatory perspective, as with impact tokens, it is necessary to create a clear regulatory framework to protect vulnerable groups from exploitation (Delfabbro et al. 2022). Thirdly, with reference to Ellinger et al. (2024), the study points out that polycentric governance models such as DAOs can promote sustainable involvement and participation in collective actions and projects through a token-based compensation system. From a management perspective, these models represent an exciting, albeit still unconventional, governance model that can enable sustainable participation in social and environmental projects. This offers the opportunity to open up new avenues for automated or semi-automated stakeholder engagement through polycentric governance systems and might support the implementation of projects through increased digital participation, crowd-funding and equitable distribution of value and benefits. Fourthly, the mining of green, decentralized currencies like EverGreenCoin might mark a significant transformation in financial models that could attract environmentally conscious investors. These currencies, commonly obtained through low carbon mining consensus mechanisms or associated with environmental initiatives or community benefits, possess an intrinsic value that may appeal to a growing subset of investors who prioritize sustainable and ethical investing (Niyazbekova et al. 2021). Management teams should consider how to position these offerings to maximize appeal and trust by emphasizing the tangible environmental benefits and robustness of the underlying blockchain technology. This requires

clearly defined communication strategies and educational measures to ensure that potential investors and users understand the benefits and functionality of these digital currencies.

6 Limitations and Future Research

This study has a few limitations that should be acknowledged to properly interpret the findings and direct future research efforts. The limitations arise primarily from the methodological approach of the Gioia method and data collection through the ReFi-DAO database. One limitation of the study is the sole reliance on grey literature, specifically company whitepapers, greenpaper and documentations. While these papers underwent a rigorous screening process and offer a comprehensive overview of the current state of the art and practice (Garousi et al. 2019), they may still have some deficiencies and biases in terms of content, such as reporting bias (Paez 2017) or selection bias (Soldani 2019). By utilizing a single database and implementing filters to guarantee the integrity of the whitepapers, there is a likelihood that some pertinent literature items, and consequently relevant ReFi applications, may have been overlooked. Additional constraints of this study may be inferred from the utilization of the Gioia method. While the Gioia method is highly effective for analyzing extensive data sets in a systematic way and creating scientific rigor in qualitative data analysis (Gioia et al. 2013), there is a potential drawback when it comes to applying the method and reducing dimensions. This approach can lead to oversimplification and overgeneralization of the data, which may result in the loss of valuable detail (Mees-Buss et al. 2022) and, in this particular scenario, application groups.

Future research efforts should begin with a clear and precise definition of the concept of ReFi to establish a guiding framework that ensures a common understanding for subsequent studies. With this shared foundation, future investigations could undertake longitudinal studies to assess the overall impact of ReFi applications, considering their social, economic, and environmental effects. Adopting a multidisciplinary approach will allow for a comprehensive understanding of the regenerative capacity of ReFi and the effectiveness of its various applications in achieving intended outcomes. This comprehensive perspective will also enable researchers to address how regenerative the ReFi ecosystem truly is. Further studies might also focus on a detailed analysis of different impact tokens and their efficiency as financial tools, as well as assess the feasibility of categorizing DAOs and impact DAOs according to their designated purpose and impact. In addition, future investigation of the economic, socio-economic and environmental impacts of X-to-Earn engagement models, such as Impact-to-Earn, may be

crucial. Such a holistic, multidisciplinary view can provide crucial insights into the benefits and potential for exploitation of vulnerable customers and thus influence the direction of future policy making. Furthermore, future research studies might conduct a backward-based analysis to explore other definitions and concepts for ReFi and investigate regenerative research that extends beyond blockchain as a fundamental framework.

7 Conclusion

Drawing on an exploratory, qualitative and systematic research approach based on the Gioia method (Gioia et al. 2013), this study presents a comprehensive taxonomy based on 21 blockchain application groups and eight overarching dimensions. The study provides an early market-driven overview of the growing ReFi ecosystem by analyzing 88 companies in the ReFi space. The development of the taxonomy enhances the scientific comprehension of ReFi and offers a comprehensive examination of how blockchain technology may be used in this emerging field to tackle social, economic, and environmental challenges.

Furthermore, the study demonstrates that the ReFi sector extends beyond the use of blockchain-based carbon credit tokens. This addresses the call made by Schletz et al. (2023) to expand research beyond the implementation of carbon credit tokens in the ReFi sector. The study shows heterogeneous application examples that include, but are not limited to, decentralized energy systems and trade, novel financial tools and tokens to finance regenerative projects, sustainable decentralized infrastructure solutions, and the use of crypto-based incentive models to encourage social and environmental friendly behaviours.

A significant result of this work is the identification and comparison of these diverse application groups with the regenerative principles proposed by Fullerton (2015) and Ostrom (2008). This analysis of the ReFi ecosystem demonstrates that, in theory, the applications have the ability to provide instruments for enhancing the economy and decentralized governance systems. Consequently, this might offer a concrete pathway towards achieving better environmental integrity and social fairness. Nevertheless, the research highlights the need of carefully examining the specific social, economic, and environmental effects of the proposed applications from a multidisciplinary perspective. It also underscores the necessity to evaluate their compatibility with regeneration both initially and constantly. This will enable future research to not only determine the extent of regenerativity in ReFi, but also assess the ethical and social integration of new technology in ecological and social initiatives and communities.

Overall, the applications examined might have the capacity to promote a transition towards more sustainable and robust economic systems using a range of mechanisms. However, according to Fullerton (2015), regenerative systems are not "à la carte" systems, but require an interplay of different solutions. Individual solutions such as tokenized carbon credit tokens, green currencies, or decentralized energy systems in isolation are insufficient to cause a fundamental change and establish a regenerative system. Nevertheless, the given study establishes an academic foundation that may be expanded upon to carry out more research that integrates and links the particular ReFI applications identified into a holistic regenerative system.

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9 Appendix

| Aggregated Dimension | Sustainable and Regenerative Blockchain Infrastructure | Decentralized Science and Blockchain for Open Access Data and Monitoring | Blockchain-Enabled Financial Tools and Ecosystems | | | | | | | Decentralized Environmental Finance and Trading Systems | | | Tokenization and Decentralization in Renewable Energy Markets | | | Crypto-driven X-to-Earn | | DePIN | Blockchain-enabled Sociotechnical Governance and Community Systems | | |
|----------------------|--|--|---|---|--|--|-----------------------------------|----------------------|--------------------------|---|------------|--|--|--|---|-----------------------------------|----------------------------------|--|--|--------------------------------------|----------|
| Application group | Low-Carbon and Carbon-Negative Blockchain Solutions Infrastructure for Decentralized Energy Applications | Decentralized Blockchain Platforms for Environmental Monitoring and Data | Decentralized Science | Blockchain-based Universal Basic Income | Blockchain-Enabled Lending and Microcredit | Blockchain-based Ecological and Community Currencies | Blockchain-based Yield Generation | Fiat-Crypto Gateways | Tokenized Carbon Credits | Recycling Credit Token | Impact NFT | Decentralized Funds for Environmental Conservation | Digital Renewable Energy Certificates and Tokenization in Energy Markets | Blockchain-based Decentralized Energy Management and Trading Systems | Crypto-driven Play-to-Earn and Impact-to-Earn | Crypto-driven Learn-to-Earn-Model | Crypto-driven Move-to-Earn Model | Decentralized Physical Infrastructure Networks | Decentralized autonomous organizations | Blockchain-based arbitration systems | |
| Company | | | | | | | | | | | | | | | | | | | | | |
| AeraForce | | | | | | | | | | | | | | | | | | | | | |
| Aquari | | | | | | | | | | | | | | | | | | | | | |
| Arkgreen | | | | | | | | | | | | | | | | | | | | | |
| Beefy | | | | | | | N.A. | | | | | | | | | | | | | | |
| Brokoli | | | | | | | | | E | | | | | | | | | | | | |
| C3 | | | | | | | | | P | | | | | | | | | | | | |
| Calo | | | | | | | | | | | | | | | | | | | | | |
| Carbon Collectible | | | | | | | | | | | | | | | | | | | | | |
| Carbon Credit | | | | | | | | | AL | | | | | | | | | | | | |
| Carbon0.fi | | | | | | | | | P | | | | | | | | | | | | |
| Carbonable | | | | | | | | | | | | | | | | | | | | | |
| Celo | C | | | | | | | | | | | | | | | | | | | | |
| ChangeBlock | | | | | | | | | | | | | | | | | | | | | |
| Circle UBI | | | | | | | | | | | | | | | | | | | | | |
| DAO IPCI | E | | | | | | GC | | | | | | | | | | | | | | |
| dClimate | | | CH | | | | | | | | | | | | | | | | | | |
| deScier | | | | E/P | | | | | | | | | | | | | | | | | |
| Earth Wallet | | | | | | | | | | N.A. | | | | | | | | | | | |
| Ecospiens | | | | | | | | | | | | | | | | | | | | | |
| Efforce | | | | | | | | | | | | | | | | | | | | | |
| Endangered Tokens | | | | | | | | | | | | | | | | | | | | | |
| EnergyWeb | | EW | | | | | | | | | | | | | | | | | | | |
| Enrex | | | | | | | | | | | | | | | | | | | | | |
| EthiHub | | | | | | | E/GC | | | | | | | | | | | | | | |
| EverGreenCoin | EC | | | | | | EC | | | | | | | | | | | | | | |
| FlowCarbon | | | | | | | | | | | | | | | | | | | | | |
| Futue Quest | | | | | | | | | | | | | | | | | | | | | |
| GaiaReFi | | | | | | | | | | | | | | | | | | | | | |
| GainForest | | | | | | | | | | | | | | | | | | | | | |
| GenoPets | | | | | | | | | | | | | | | | | | | | | |
| Giveth | | | | | | | | | | | | | | | | | | | | | |
| GoodDollar | | | | | | | E | | | | | | | | | | | | | | |
| Grassroots Eco. | | | | | | | | | | | | | | | | | | | | | |
| Greeneum | | | | | | | | | | | | | | | | | | | | | |
| Grid Singularity | | | | | | | | | | | | | | | | | | | | | |
| H20 Securities | | | | | | | | | | | | | | | | | | | | | |
| Hara | | | E | | | | | | | | | | | | | | | | | | |
| HaloFi | | | | | | | | | | | | | | | | | | | | | |
| HomeDAO | | | | | | | | | | | | | | | | | | | | | |
| Impact Market | | | | | | | C | C | | | | | | | | | | | | | |
| ImpactScope | | | | | | | | | | | | | | | | | | | | | |
| IXO World | CS | | | | | | | | | | | | | | | | | | | | |
| Kleros | | | | | | | | | | | | | | | | | | | | | |
| KlimaDAO | | | | | | | | | | | | | | | | | | | | | |
| Kokomut DAO | | | | | | | | | | | | | | | | | | | | | |
| Kotani Pay | | | | | | | | | | | | | | | | | | | | | |
| Likvidi | | | | | | | | | | | | | | | | | | | | | |
| Litter Token | | | | | | | | | | | | | | | | | | | | | |
| Meta Gym | | | | | | | | | | | | | | | | | | | | | |
| Metamazonia | | | | | | | | | | | | | | | | | | | | | |
| MetaTrees | | | | | | | | | | | | | | | | | | | | | |
| Mintera | | | | | | | | | | | | | | | | | | | | | |
| Mosla Market | | | | | | | C | | | | | | | | | | | | | | |
| Moss | | | | | | | | | | | | | | | | | | | | | |
| Nori | | | | | | | | | | | | | | | | | | | | | |
| OliveX | | | | | | | | | | | | | | | | | | | | | |
| Open Earth | | | | | | | | | | | | | | | | | | | | | |
| Open Forest | | | | | | | | | | | | | | | | | | | | | |
| Oxygen Chain | | | | | | | | | | | | | | | | | | | | | |
| Oxygen Chain | | | | | | | | | | | | | | | | | | | | | |
| PieDAO | | | | | | | | | | | | | | | | | | | | | |
| PieDAO | | | | | | | | | | | | | | | | | | | | | |
| PlantGang | | | | | | | | | | | | | | | | | | | | | |
| Plastiks | | | | | | | | | | | | | | | | | | | | | |
| PotLock | | | | | | | | | | | | | | | | | | | | | |
| Powerledger | | | | | | | | | | | | | | | | | | | | | |
| Powerledger | | | | | | | | | | | | | | | | | | | | | |
| Quantum Temple | | | | | | | | | | | | | | | | | | | | | |
| RegenLedger | | | | | | | | | | | | | | | | | | | | | |
| RegenLedger | | | | | | | | | | | | | | | | | | | | | |
| Reneum | | | | | | | | | | | | | | | | | | | | | |
| ReverseC. DAO | | | | | | | | | | | | | | | | | | | | | |
| Rowan | | | | | | | | | | | | | | | | | | | | | |
| Rowan | | | | | | | | | | | | | | | | | | | | | |
| Seeds | | | | | | | | | | | | | | | | | | | | | |
| Single.Earth | | | | | | | | | | | | | | | | | | | | | |
| Sintrop | | | | | | | | | | | | | | | | | | | | | |
| Sintrop | | | | | | | | | | | | | | | | | | | | | |
| Solarpunk | | | | | | | | | | | | | | | | | | | | | |
| Solarpunk | | | | | | | | | | | | | | | | | | | | | |
| Solid World | | | | | | | | | | | | | | | | | | | | | |
| Sovereign Nature | | | | | | | | | | | | | | | | | | | | | |
| Sovereign Nature | | | | | | | | | | | | | | | | | | | | | |
| Stable Credit | | | | | | | | | | | | | | | | | | | | | |
| Stable Credit | | | | | | | | | | | | | | | | | | | | | |
| Stepn | | | | | | | | | | | | | | | | | | | | | |
| Stepn | | | | | | | | | | | | | | | | | | | | | |
| SunContract | | | | | | | | | | | | | | | | | | | | | |
| SunContract | | | | | | | | | | | | | | | | | | | | | |
| Sunrise Stake | | | | | | | | | | | | | | | | | | | | | |
| Sunrise Stake | | | | | | | | | | | | | | | | | | | | | |
| Symmetric | | | | | | | | | | | | | | | | | | | | | |
| Symmetric | | | | | | | | | | | | | | | | | | | | | |
| Thallo | | | | | | | | | | | | | | | | | | | | | |
| Thallo | | | | | | | | | | | | | | | | | | | | | |
| The Space | | | | | | | | | | | | | | | | | | | | | |
| The Space | | | | | | | | | | | | | | | | | | | | | |
| Toucan | | | | | | | | | | | | | | | | | | | | | |
| Toucan | | | | | | | | | | | | | | | | | | | | | |
| Treedefi | | | | | | | | | | | | | | | | | | | | | |
| Treedefi | | | | | | | | | | | | | | | | | | | | | |
| VeChain | | | | | | | | | | | | | | | | | | | | | |
| VeChain | | | | | | | | | | | | | | | | | | | | | |
| VitaDAO | | | | | | | | | | | | | | | | | | | | | |
| VitaDAO | | | | | | | | | | | | | | | | | | | | | |
| Wheelcom | | | | | | | | | | | | | | | | | | | | | |
| Wheelcom | | | | | | | | | | | | | | | | | | | | | |
| Zelooop | | | | | | | | | | | | | | | | | | | | | |
| Zelooop | | | | | | | | | | | | | | | | | | | | | |
| Count | 6 | 3 | 4 | 3 | 4 | 5 | 7 | 6 | 3 | 17 | 5 | 12 | 5 | 7 | 4 | 10 | 2 | 6 | 3 | 42 | 1 |

Algorand (AL), Arbitrum (AR), BNB (B), Celo (C), Chainlink (CH), Cosmos SDK (CS), Ektacoin (EK), Energy Web Chain (EW), EOSIO (EO), Ethereum (E), EverGreenCoin-Blockchain (EC), Gnosis Chain (GC), Hyperledger Besu (HB), Kitab Chain (KC), Multichain Protocol (MC), NEAR (N), Not specified (N.A.), Oxygen-Chain (O), Polkadot (PL), Polygon (P), Powerledger (PW), Regen Ledger built on Cosmos SDK (RL), Rowan (RO), Solana (S), Tezos (T), VeChain Thor (V).

Appendix 1: Underlying companies and data basis of the taxonomy

Source: Own representation