Nature Based Currencies:
Integrating natural capital in advanced monetary systems

WHITEPAPER DRAFT v1
DESIGN ITERATION: Central Bank perspective

OpenEarth
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ABSTRACT
In this paper, we explore the concept of Nature-Based Currencies (NBCs) and their potential to integrate natural capital into advanced monetary systems, with the aim of avoiding global ecological collapse and promoting geopolitical equity. We discuss the issues in global north–south relations, extractive economies, and the failure of traditional economic systems to properly account and value natural capital, leading to environmental degradation and social inequality. We present NBCs as a promising solution by valuing global living capital as a key component of economic systems. We propose a framework for NBCs and present new innovations from the digitization space that could underpin equitable and sustainable monetary systems. We examine approaches for NBC development across traditional and nontraditional financial systems and programmatically design a first iteration from the perspective of central banks. Specifically, we introduce a mechanism for a Nature-Based Central Bank Digital Currency (NB-CBDC) as a way to issue novel financial capital with programmed incentives for protecting nature. However, we also critique this model and explore why other design iterations would be beneficial. Overall, this paper provides initial insights and a thought experiment into designing equitable financial and monetary systems that intrinsically value nature, prioritizing both human well-being and planetary health.

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1. Introduction & Problem Statement

The world faces an imminent ecological crisis threatening the stability and feasibility of thriving life on Earth. The carbon budget for keeping warming below 1.5°C will most likely be breached in the next six years, triggering cascading tipping points. Loss of terrestrial and marine biodiversity and habitat has eroded the integrity of the world’s biospheres, causing species extinction and the irreversible loss of genetic building blocks of life. Ecological collapse causes both economic and social instability. Multinational organizations and national governments have established two major policy frameworks to counter these catastrophic effects: the Paris Agreement, which seeks to prevent warming beyond 2°C above pre-industrial levels, with additional efforts to stay within 1.5°C; and the Global Biodiversity Framework (GBF) established in COP15, which seeks to conserve 30% of land and ocean ecosystems by the year 2030.

According to World Bank estimates, effectively mitigating climate change would require around $1.5 trillion in annual capital deployment through mid-century, while a 30% global conservation would demand similar outlays over the next 10 years. Where is this capital expected to come from? And what barriers are preventing deployment at the rate needed to avoid existential threats? From one perspective, the world is well equipped to deploy the necessary financing, equal to only 3% of global GDP—a fraction of the 15% of GDP mobilized in response to the Covid pandemic. Yet from another perspective, the needed financing cannot be achieved with current political dynamics. Debates over equity and which country should be responsible for how much funding has led to international deadlock and is widening a division between the Global North and South—essentially industrialized and less industrialized nations.

Putting aside the economic and political feasibility of mitigating total ecological collapse, this issue speaks to a more fundamental problem that needs to be addressed. It involves revising the social agreement on what we value as a civilization, and how this affects the core of our monetary system and economic paradigm. The global economy has a total asset valuation of around $500 trillion, but ecological systems and living beings are often valued more when they are dead than when they are alive. This economic model creates a growing divide between people and the natural world. The current economic and financial system not only fails to account for the negative effects associated with many economic activities, but also encourages the accumulation of an enormous deficit of value, amounting to hundreds of trillions of dollars. This debt is now reflected in uninsurable liabilities that will lead to total losses if the current trajectory of climate and ecological collapse continues, posing an existential crisis for the re-insurance sector.

The way we understand and measure wealth, especially at the national level, is currently undergoing a significant shift. Both traditional and non–traditional institutions are part of this evolution in our understanding of wealth. The World Bank’s “Changing Wealth of Nations” report, for example, recognizes that GDP is no longer sufficient as an indicator of a country’s wealth. The report argues that natural and cultural value must be given a more prominent role in a new wealth paradigm.

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2 World Bank (2019), Beyond the Gap Report.
In addition, the United Nations has been working on the System of Environment and Economic Accounting (SEEA) over the last decade. This system aims to establish methodologies for natural capital accounting and translate them into economic capital. Its objective is to value all the components of ecosystem services and represent them in aggregate in environmental accounts. SEEA holds the potential to better articulate the interrelationship of natural systems. However, it is worth noting that these frameworks are designed primarily to enhance policymaking rather than to create financial capital.

In nontraditional institutions, the advance of distributed ledger technologies (DLT) with algorithmic consensus (e.g., blockchains) has introduced new tools used to design financial instruments, enhance decentralized governance, and develop self-executing policies and contracts. The growing interest and burgeoning research in Central Bank Digital Currencies (CBDC) is expanding the possibilities for digital practices and their ability to transform the monetary landscape. DLTs’ application in the design of ecological economics has already led to new mechanisms for trading ecological value. The integration of internet-connected sensors (i.e., IoT), artificial intelligence, and blockchains allows for ecological health to be linked with dynamic financial instruments. But like all tools, these novel instruments are only useful to the extent that they are designed and implemented intelligently and with purpose. Core principles must be established to guide the design and application of scalable financial and economic mechanisms that would catalyze a transition to a global economy that values and regenerates natural capital.

1.1 White paper agenda

In this whitepaper we develop and propose principles and guidelines for building ecological and financial instruments in an advanced monetary system, those specifically designed with incentives to avert ecological collapse and value a thriving planet. The central goal is to create frameworks and paradigms that value Nature in a manner that incentivizes the preservation, restoration, and enhancement of the natural world and that would thereby help to maintain livable conditions on our planet. This project would entail grounding the traditional and nontraditional institutions that drive contemporary planetary financial and economic activity in nature-based approaches. This white paper considers examples of two systems: (i) the central banking system, a traditional system and (ii) the Regenerative Finance (ReFi) system in the Web3 economy, a nontraditional system. We develop scenarios exploring what it would mean for these systems to issue nature based digital currencies (NBDC), in part to finance conservation and climate action operations, recognizing the private banking and corporate sector as a “middle ground” between them. Specifically, we explore Nature Based Central Bank Digital Currencies (NB–CBDC) and their potential use in central bank operations.

We utilize a programmatic design process for designing and conducting an NBDC thought experiment. This process entailed first deriving a conceptual framework based on set intentions and a landscape assessment of relevant topics, and then applying this framework to a strategic sector to produce a system design. The design proposed (in this first case a NB–CBDC) can then be reviewed, iterated, and piloted to test if it meets its design goals. This process allows for a transparent review of why and how a system is proposed and enables continuous revision of the underlying framework and its application across different economic sectors. Figure 0 outlines the process and aligns it with the whitepaper’s structure.

Section 2 gives the context and motivation for this work, describing the need to address geopolitical equity and the need for a clear, universal notion of living capital. Section 3 proposes a revision of the

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fundamentals of central banking mechanics and presents new innovations from the digitization space and the current landscape of nature-derived financial instruments. Section 4 derives a framework for NBDCs, describing its main pillars with guidelines for the transmission of monetary policies to the natural sector and direct incorporation of natural capital into balance sheets and reserve assets. Section 5 explores approaches and dynamics for NBDC development and deployment across a spectrum of more and less traditional economic sectors. We conclude with forward-looking scenarios of the application of NBDCs for conservation in seminal bioregions like the Galapagos marine corridor and the Amazon rainforest, as well as with a forward-looking research and implementation roadmap.

**Figure 0. Programmatic Design process and content structure for the whitepaper.** The paper provides a broad review of global finance’s current landscape and introduces a framework for designing NBDCs, providing a first iteration from a central bank perspective, while noting how the process can be reiterated and improved to apply to other sectors.

**2. Motivations for designing equitable financial instruments that value a living planet**

This paper’s fundamental goal is to explore ways for our economic system to properly value nature and create incentives to protect the natural world and its resources. This new economic paradigm must be envisioned and applied in a way that considers equity from a geopolitical and intergenerational standpoint while retaining the incentives necessary to create a regenerative economy out of an
extractive one, and while incorporating both the “living” quality of nature and the role of local stakeholders, particularly indigenous communities.

2.1 Global North-South Equity Gap in natural and financial capital

Since at least 1971, the footprint of global economic systems of extraction has exceeded the Earth’s capacity for sustainable regeneration. By 2022, we had depleted the bio-regenerative capacity of the Earth by 1.75x, and we are continuously incurring a growing bio-capacity deficit. This trend means that Earth will be able to sustain less and less life, meaning lower populations of human, animal, and plants. There are no current financial or economic incentives to remedy this problem at scale, spelling an existential crisis that, if left unchecked, will make the Earth uninhabitable for all but a few highly resilient species.

Figure 1 - Biocapacity overshoot. Humanity’s annual resource consumption far out-paces Earth’s capacity to regenerate what is used. In 2022, the human civilization had consumed all resources that Earth regenerates in a year by the month of August; everything consumed in the remaining months was in excess of this planetary capacity and thus contributed to an overshoot. Source: Global Footprint Network.

The present predicament demands an immediate shift away from an extractive model of value, and it points to the geopolitical dynamics and economic imbalances that current modes of valuation have produced. Developing nations have debt to and asymmetries with wealthier countries in relation to both currency and power. These poorer nations bear the brunt of climate change, a calamity for which they have not been the principal cause, and they will need to invest in new technologies to promote growth while mitigating climate change’s deleterious effects. Furthermore, these nations of the global south are the principal guardians of critical natural resources, yet have internal and external pressure for them to ramp up extractive industries within their borders.

Most of the remaining pristine natural resources and biodiversity are located in developing countries in the Global South or in largely uninhabited regions such as international waters, polar regions, Siberia and Greenland. These natural resources are targets of exploitation, extraction and destruction, especially in Brazil, the Congo, the African “Great Green Wall”, and Indonesia. Once gone, they are lost forever. These ecosystems of life, regeneration and carbon extraction are currently valued only as extractable, fungible, 

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6 Global Footprint Network (footprintnetwork.org).
and expendable assets. The countries in which these vital and irreplaceable resources reside have little financial and economic leverage against the industrial economic powers of the West and China. Yet from an ecological market perspective, natural capital in the Global South is higher in value because it is the most threatened — market mechanisms have a greater ‘additional’ impact here than they would in the North.

In the past 20 years of UNFCCC climate negotiations, the North–South division has become the root of deadlock in climate progress and financial commitments. The 2015 Paris Agreement codified “common but differentiated responsibilities” for the world’s nations acting on climate change, yet the North–South divide has stoked vigorous debate in negotiations around ‘loss & damage,’ ‘adaptation finance,’ ‘technology transfer’ and climate ambition, stalling the entire geopolitical agenda. If we are to transform the global economic paradigm and monetary system, the new system must yield financial sovereignty back to global south nations and prevent rapacious extraction of natural capital from their lands and waters.

2.1 Extractive vs Regenerative Economies

The transition from an extractive economy to a regenerative economy is central to this paper’s discussion. The nature-based instruments discussed in section 5 are initial ideas meant to address the problems of how to factor nature into decision-making and how to intrinsically value nature in our economy and architected within our monetary system. This topic may concern central banks and inform a nature-based CBDC design. Additionally, we seek to explore to incorporate nature as a group of protected assets that generate value when left intact, and how this can be reflected dynamically on a balance sheet. These questions directly pertain to the ReFi sector where financial institutions would need to embed continuous monitoring, reporting and verification of ecological states into digital assets.

![Figure 2. From Extractive to Regenerative Economies.](image)

Financial sector assets exchanged in an extractive economy derive their value from the fact that they can be exchanged. That is, assets in extractive economies have value because they can be displaced at a precise time, either physically (e.g., extracting coal when the demand is high) or legally (e.g., acquisition of a property right when supply is high). These displacements create arbitrage opportunities that represent a core pillar of value creation in extractive economies, as described by the mantra: buy low, sell high, enter, time, exit. Extractive economies are less problematic if resources are unlimited, or if the normal regeneration rate of the extracted resource outpaces the rate at which resources are physically displaced (e.g., if the regeneration of forests outpaces the rate of timber production), or if the rate at
which assets are legally displaced outpaces the rate at which these assets are produced (e.g., if consumption balances production). Remaining within the bounds of stability of extractive economies is not easy. In fact, we have passed the point in history at which extractive economies could operate sustainably and at which their externalities could be judiciously managed.

Regenerative economics is built on the common economic relation, the principle that maintains the co-benefits of parties. This process generally involves an agreement on personal rights, instead of a pact on the exploitation of an arbitrage by the acquisition and alienation of real rights (e.g., the buyer–seller relation). Regeneration, as a concept of recurring value production, is not new. Consider, for instance, the landlord–tenant relationship. In an ideal such relation, both the tenant and the landlord meet their obligations regarding the maintenance of the accommodation, and costs remain viable for both parties (e.g., the rent increases steadily, and the payments are made in due time). Each party's benefit is correlative to the other, and the net effect of this arrangement is the preservation of the relation and of the accommodation. Regenerative value here is derived from the stability of the relation over time, not from the potential of that relation to afford a profitable exit at the right time. This example can be analogized to consider humans as tenants, and the Earth system as the landlord.

The perspective of a regenerative economy as one that preserves relationships is not only applicable to simple relationships, but also to entire living systems. Thus, Living Capital should be considered distinct from Natural Capital, with Living Capital referring exclusively to the emergent value generated from living ecosystems, and Natural Capital being a more general term than could include specific assets, like timber and other natural resources, including metals and minerals, like gold. A regenerative economy’s monetary system must include Natural Resources on the “balance sheet,” yet do so in a way that does not devalue the living ecological systems these resources come from. These living systems also need to be accounted for on the balance sheet and factored into indicators and computational models that institutions use to make economic and financial decisions.

The remainder of this paper explores how institutions, such as central banks, and regenerative finance protocols could develop instruments to “bring natural resources on the balance sheet while preserving living capital”. One such instrument for central banks could be Nature Based Central Bank Digital Currencies (NB–CBDC), which could be used to support the “natural sector” of the economy – a sector not typically considered in policy-making processes, often due to a lack of adequate measures of natural capital. For ReFi protocols, these instruments could take many forms, including web3 and crypto-based digital currencies. We will refer to both central banks NB–CBDC and ReFi NBDC as types of a broader Nature Based Digital Currencies (NBDC); the former being an NBDC issued by central banks, and the latter an NBDC issued by other entities.

3. A Review of central banking, CBDCs and Regenerative Finance (ReFi)

Global currency systems are not backed by any tangible asset. That approach was abandoned in 1971 when President Nixon took the US off the gold standard and Bretton Woods system in an effort to thwart a redemption run by foreign investors on US gold supplies during a period of high inflation. Whereas collateral or “backing” are often required for private credit or typical commercial and consumer credit

transactions, this backing is not required at the Federal level. Figures 3 and 4 illustrate key concepts of money, backing and currencies.

The value of a currency, that is, its ability to function as a legal means of payment, is dependent upon its government’s ability to enforce its use as “legal tender” and upon the liquidity and perceived utility and stability of that currency. This concept reminds us that money is a social contract – given that society creates money, it can manipulate currencies to serve its collective purpose. This section reviews key concepts regarding the fundamentals of currencies as applied in the central banking system and in the web3 ReFi economy. Understanding this context and money concepts is essential to designing effective nature-based instruments and currencies for these systems.

**Figure 3. Abstract components of what “backs” currencies and financial instruments.** In the far left is the Pre-Bretton Woods system gold-backed currency paradigm, and next to it is the policy-backed fiat currency post-Bretton Woods monetary design. Analogous to the backing in other financial instruments, the diagram on the right shows how collateral can be used to back or give value to an associated instrument, e.g., a derivative.

**Figure 4.** The term “payment” refers to the process of settling a debt owed by a debtor to a creditor. The way in which a debt is settled can vary depending on the nature of the debt. Payment arrangements are usually agreed upon by contract and can be made through the exchange of a medium of exchange, like money or currency (such as a $10 transfer or cash), or through some other form of action, like not doing something. In many western payment systems, there is a universal way to settle debts, regardless of the payment arrangement agreed upon in the contract. This universal means of payment is typically a currency that functions as “legal tender”. When a currency is designated as “legal tender”, an entity is legally obliged to accept it in exchange for settling a debt. Money is a type of medium of exchange that is accepted as payment, like fiat currency. It serves as a store of value that is stable over time and as a unit of account that helps to measure the value of things. Different currencies are considered “money”, but not all payment instruments fall under this category. For example, a check is not considered “money”, but it can be agreed upon in a contract as a “means of payment”.

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**Payment Instruments**

**Money**

**Currency**
1. Official means of payment (legal tender)
2. Recognized by monetary law
3. Issued by central banks
4. Denominated in the official monetary unity
5. E.g., bank notes and coins

1. E.g., currency and assets convertible into currency such as credit balance
2. Is not a legal tender
3. Is not money
4. E.g., checks
### 3.1 The mechanics of central banks and opportunities for CBDC

#### 3.1.1 Central bank digital currencies: potential leverage and transformation points

Central banks are institutions with various degrees of autonomy from their government’s executive branch, which have been established by law (e.g., the Bank of Canada Act, 1985). These banks are often the natural guarantors of a country’s financial stability, as they are the only providers of legal means of payment (i.e., of legal tender such as national currencies). Among the payment instruments issued by central banks, a new class – Central Bank Digital Currencies (CBDCs) – is drawing increasing levels of scrutiny and research. As a liability of central banks, CBDCs must conform to the legal constraints that apply to central banks, a constraint that dictates their structure and design (see appendix A).

The U.S. Federal Reserve defines CBDCs as “a digital liability of a central bank that is widely available to the public.” Today in the United States, Federal Reserve notes (i.e., physical currency) are the only type of central bank money available to the general public. Like existing forms of money, a CBDC would enable any citizen to make digital payments. As a liability of the Federal Reserve, however, a CBDC would be the safest digital asset available to the public, with no associated credit or liquidity risk. In other words, instead of banknotes being the sole form of “legal tender” there would be a digital version backed simply by the “rule of law”. Meaning that when the bearer of the banknote or bill is “tendered” in payment, the “creditor is legally obligated to accept legal tender toward repayment of a debt.” Whereas Apple Pay and Alipay were private versions of a digital payment system, the CBDC would be a public payment system backed by the central bank.

#### 3.1.2 The mechanics of central banks and its levers to the economy

Three aspects of typical central bank mandates must be considered when designing a CBDC project. The first are its "objectives", which are the tenets that motivate the operations of the central bank. The second are its "functions", or duties, which correspond to what a central bank is allowed to do to achieve its objectives. The third are its "powers", which define what kinds of operations a central bank has access to implement their objectives. Although this will change depending on the law that authorizes a central bank, many central banks, such as the American Federal Reserve, will have objectives to develop monetary policies that promote (i) sustainable economic output and employment, (ii) moderate interest rates, and (iii) inflation stability. Functions to note with respect to CBDC are the issuance of currency and the establishment of a payment system. In line with its functions, central banks also have the powers to produce, circulate, and withdraw banknotes and coins (e.g., mint and issue currencies), and to open bank accounts and hold cash current accounts in the books of the central bank. This power allows central banks to act as the “bankers of the private banks,” which is key to the tools that central banks have at their disposal to reach their objectives. This will also be key to our discussion in section 5.

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To achieve their mandate and implement monetary policies, central banks have access to tools such as Open Market Operations (OMO) and quantitative easing that are designed to influence the economy. These tools act over the variables that central banks can control (e.g., money supply in the economy and interest rates) and affect uncontrolled variables (e.g., inflation, output, employment, consumption, and investment). For instance, a conventional tool like OMOs will inject liquidity in the economy to change the interest rates that private banks charge to borrow and lend money to one another, thereby influencing the interests that private banks offer to their end customers (e.g., firms and households), which influences economic activity of the real sector. The “channel” whereby actions on variables controlled by central banks influence uncontrolled variables in the economy, and the degree in which this influence happens, is what’s known as the transmission mechanism of monetary policies\textsuperscript{13}.

To achieve the objectives of their mandate, central banks only have access to a limited amount of control variables, which relate to uncontrolled and unknown variables in a complex and non-linear fashion. For that reason, central banks must base their decisions on mathematical models that attempt to explain and predict how change in a controlled, known variable will propagate through economic channels to influence uncontrolled, unknown variables (e.g., dynamic stochastic general equilibrium (DSGE) models\textsuperscript{14}).

In summary, the “mechanics” of central banks include components such as the mandate of a central bank, the tools at its disposal to accomplish its mandate, and the economic channels through which central banks can act. Central banks have objectives (e.g., monetary policy to control inflation) which are achieved through functions and powers (e.g., minting and issuing currencies) that operate through tools (e.g., Open Market Operations) that act on controlled variables (e.g., interest rates). Through economic channels, controlled variables influence non-linearly and in a complex fashion uncontrolled variables (e.g., employment rate); hence to achieve their objectives, central banks must use mathematical models that capture the influence between controlled and uncontrolled variables characteristic of this influence relation: the transmission mechanism of monetary policies (see figure 5).

Any project that aims at supplementing or complementing the mechanics of a central bank must consider how the components of those mechanics relate to one another and remain coherent with those components. Accordingly, a nature-based currency, which contemplates the involvement of central banks and tools such as a CBDC, should consider how such a novel instrument fits within the current mechanics of a central bank.


Figure 5. The mechanics of central banks. This figure summarizes what we called the “mechanics” of central banks. From top to bottom, it illustrates how, informed by economic models, central banks make expansionary and contractionary policy decisions that target known, or “controlled” variables such as the federal funds rate and money supply. Controlled variables influence unknown, or “uncontrolled” variables in the financial and real sectors of the economy. The fact that controlled and uncontrolled variables are related allows for the “transmission” of monetary policies to the financial and real sectors. Note that here, we did not explicitly represent some important aspects of the system within which the mechanics of central banks operate, such as “expectations” (e.g., how some markets may behave in response to future policy), and “shocks” (e.g., how contingencies like supply chain disruption may contribute to destabilizing the economy).

3.2 Legacy and modern nature-based financial instruments and Web3 mechanisms (ReFi)

This section reviews a selection of traditional nature-based financial instruments, examining their application to natural capital assets and their potential role in NBDC development. The section also discusses new mechanisms and opportunities that arise from Web3 and blockchain involvement in the domain of environmental assets and finance (i.e. ReFi).

3.2.1 Legacy and modern nature-based financial instruments

Transforming environmental value into financial assets is not a new practice. It is important for the development of novel NBDCs to review existing instruments that fall either in the commodity or security classification and to identify mechanisms that fall in neither category.

Ecological credits

Traditional carbon credits, either in voluntary or compliance markets, are a form of ecological credit that are legally understood as commodities. These credits are an asset representing a distinct service that can be ‘consumed,’ meaning an entity will buy and retire them (i.e. remove them from the market) and then claim the ecological benefits they represent under the buyer’s name (e.g. 1 Ton of CO\textsubscript{2} reduction). If the entity retires them to compensate for emissions or ecological impacts that occurred elsewhere, then they are considered an ‘offset.’
To trade environmental assets as commodities, market actors must accept and abide by certain standards and methodologies and operate within established registries. While compliance markets have strict ‘top-down’ guidelines within the legal purview of their jurisdictions, voluntary carbon markets have less structured regulations and depend largely on buyers trusting the rigor behind the standard, verification, registry, and marketplace in which they are being purchased. Commodities in ecological markets are very relevant to NBDC exploration for two main reasons. The first is that traditional currencies have been backed by commodities (i.e. gold), and second, the mechanics of retiring an ecological commodity accounts for its service either in the jurisdiction where it was produced or where the buyer retires it — in which case both jurisdictions would need to establish corresponding adjustments to reflect the movement. While carbon credits have predominantly dominated ecological markets, environmental commodities also exist for water and, increasingly, other ecological values such as biodiversity15.

**Green Bonds**

Another important nature-based financial instrument, which may or may not act in concert with ecological credits, are Green Bonds. Based on different variations, Green Bonds are also known in some cases as climate bonds or more broadly as sustainability-linked bonds. Essentially, these are debt instruments which are issued to finance the costs of projects that have environmental outcomes. They hold the traditional properties of bonds, meaning they are sold at a face value, have scheduled interest or coupons, and can be traded in primary or secondary markets. Because they are bonds, they are considered securities and governed under securities law. An environmental project developer could issue a green bond via a broker to develop a project that will then also issue ecological credits. However, green bonds do not have the same strict set of methodologies for monitoring, reporting and verification (MRV) of the environmental value they produce. Just as with ecological credits, some are more ‘green’ than others, based on the underlying rigor of the ecological claim and outcome16.

**Payment for ecosystem services**

Governments have increasingly relied on payment for ecosystem services (PES) to incentivize landowners and farmers to adopt certain ecological practices or move away from destructive environmental practices. These payments do not involve concrete tradeable assets and fall neither in the securities nor commodities bucket. Often, funds for these payments are sourced through taxes elsewhere in the economy (e.g. a fuel tax) and are often issued with lower MRV requirements than ecological credits. Nevertheless, PES are very relevant to this paper for two main reasons: First, PES legitimized the broad concept of ecosystem services; and second, PES create a payment channel between the public and private sector to influence ecological behavior intended to raise the natural capital of a country or region. For example, through the FONAFIFO PES program in Costa Rica, the government has successfully reverted alarming deforestation rates in the late 1980s and now holds one of the largest forest coverage % of national territory17.

**Debt-for-Nature Swap**

A key environmental mechanism that plays into the equity dynamics between the global north and south described earlier, is that of debt-for-nature swaps. Under this mechanism, a debtor country (often from the global south) will cancel the debt it has with a creditor country (often from the global north) by investing in and growing its natural capital. There are different variations for Nature swap. Some are direct bilateral agreements while others also include an NGO intermediary which will purchase the debt from the creditor country and establish financial arrangements with the debtor country. Irrespective of variations, perhaps the most important aspect from a financial standpoint, is that the conservation actions are incurred using the local currency of the debtor, and the debt if forgiven at foreign currency of the creditor. This currency arbitrage can be significant if the debtor currency is weak and the creditor

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15 See for example, https://www.oecd.org/environment/resources/Policy-Highlights-Biodiversity-Offsets-web.pdf
currency strong—which is often the case due to north–south dynamics described earlier. Nature–debt swaps are extremely relevant for the discussion of nature–based currencies because they directly translate and recognizes natural capital into financial capital and, second, they provide an opportunity for balancing geopolitical imbalances in economy and natural resources.

Scaling debt–for–nature swaps are complex for two reasons. First, if the mechanism moves from strictly bilateral to multilateral relationships, the level of complexity to orchestrate agreements across countries, currencies, and conservation action valuation increases (...). The second is that they require a creditor country willing to value the increase of natural capital of their foreign counterpart. While many economically powerful countries have assigned budgets for international development related to climate and conservation, these are not enough to cancel all the international financial debt. The vision of a NBDC that is accepted as international tender could potentially scale and empower debtor countries to cancel their debts through financial capital that they mint, derived from a significant increase in the national natural capital stocks.

**Fig 6. Debt for nature swaps.** Illustration of the dynamics between creditor and debtor nations. Ideally, the process involves a process to monitor and verify ecological value to guarantee the debt forgiveness. The squared grid represents nature inventory records with diverse services.

**Natural Asset Companies**

The most modern nature–based instrument worth reviewing is that of a Natural Asset Company. This model has been pioneering by a private company called Intrinsic Exchange Group, to essentially identify a mechanism to turn natural capital into financial capital. The Natural Asset Company is a corporation that has legal tenure over an ecologically valuable property, holds a robust inventory of the property’s natural capital and associated ecosystem services, and whose stocks trade publicly in a stock exchange via an IPO (Initial Public Offering). The first pilot of this mechanism is being done in partnership with the New York Stock Exchange and involves companies and properties in Costa Rica and the other pristine places in the Global South. The trading stock of a Natural Asset Company is a relevant innovation for nature–based currencies because it is a natural capital security that can be held in a treasury to back another financial derivative or act as an environmental collateral.
3.2.2 Blockchain–enabled Regenerative Finance (ReFi)

Regenerative Finance, or “ReFi” is an Internet community–driven movement that uses Decentralized Ledger Technologies (DLT) such as blockchains to build systems and protocols aimed at financing regenerative activities such as the protection of natural environments. A central component of ReFi protocols is the creation of digital tokens, which can play a wide array of functions, from tradable units of ownership of an underlying asset, to unique instruments that allows a holder to vote on a collective governance decision. The role of and interest in blockchains–based tokens and smart contracts in the environmental space has grown significantly in recent years, with researchers and practitioners focusing on these tools’ conceptual technological potential – namely, the potential to create robust units of ecological accounts by linking them to a recurring digital MRV process and state, to avoid double counting in market trades, to establish data integrity when attesting to ecological claims, and to facilitate the automation of multi–party rules and contracts for innovative business models and governance dynamics.

ReFi is a relatively new term that encompasses multiple activities, use–cases and organizations at the intersection of blockchain, climate and environmental finance. The movement borrows from toolkits used in the DeFi (Decentralized Finance) space, such as digital stablecoins and ‘staking rewards’ (i.e., the reward one ongoingly receives when allowing the protocol to keep one’s token). The growth of and interest in ReFi increased in 2021 when novel financial instruments were created from the tokenization of carbon credits from the voluntary market. In September 2021, the creation of the Klima DAO token (KLIMA), which is backed by tokenized carbon credits locked in a digital treasury, was an inflection point for the movement. Via smart contracts, the environmental assets in the Klima treasury act as a reserve for the newly circulating digital currency. The Klima DAO was launched as a Decentralized Autonomous Organization, meaning a digitally governed corporation where anyone that acquires the right set of tokens can participate in collective decision–making and governance. Certain organizational decisions can only be made by the Klima community rather than its creators or core contributors.

The KLIMA token system has notable issues. It is vulnerable to investment speculators, which can lead to “boom and bust” market dynamics, and its design of the treasury–to–asset value dynamic could be improved to better represent the distinctive and dynamic qualities of the carbon credit assets in its reserve baskets. Despite its flaws, this innovation demonstrates the mechanics essential to creating
nature-based digital derivatives. Because open-source software is the building blocks of the entire blockchain and Web3 space, the innovation rate to replicate, improve, tweak and re-deploy auditable digital financial infrastructure is unprecedented. The ReFi concept entails robust digital layers that could power the nature-based instruments and dynamics mentioned in the previous section, including carbon credits, green bonds and independently verified ecological claims among natural asset companies or nature-debt swaps. Figure 8 presents a summary of legacy nature-based instruments and the role of ReFi as an augmented digital layer. Automation and physical-to-digital linkages (eg. on-the-ground ecological changes are immediately reflected on the derived digital instrument’s value or units) are a key promise of the ReFi space, one that is centrally relevant to NBDCs. The integration of both finance functions and governance is also worth noting, given that natural capital is often represented as Common Pool Resources where multiple stakeholders depend on their collective decisions and coordination to ensure sustainable management of the resource.

Fig 8. Legacy Nature-based instruments and the blockchain-enabled ReFi space. Illustration of the dynamics involved in a traditional Ecological Credit such as carbon credit used for offsetting (i.e. environmental commodities) and a Green Bond (i.e. a securities). On the left, the web3 enabled ReFi space involves digitizing all these variables from the legacy system and can support new instruments which can dynamically derive its value based on underlying assets (eg. derivatives and carbon-backed tokens).
4 An Integrated Framework for Nature-Based Currencies

The primary proposition of this programmatic work and report is that nature based currencies, whether they are issued by central banks or by private entities in the Web3 space, have the potential to transform an extractive economy by embedding nature and a living planet as the fundamental reserve and asset backing our monetary systems. These novel financial tools could bring much needed support to address the climate and biodiversity crises and avoid trillions of uninsurable losses arising from crossing planetary tipping points. If poorly designed, however, these instruments may have unintended consequences that help maintain an extractive model through short term market opportunism.

We anticipate that, within a few years, there will be several NBDC initiatives with diverse approaches to their design, both in traditional and non–traditional sectors. A level of coordination and standardization is needed to ensure that these approaches are effective. Incorporating considerations and dynamics reviewed in previous sections, we propose here a 6–part framework of components and concepts for the design and issuance of NBDCs, irrespective of economic sector.

Figure 9. Framework Diagram and pillars for Nature Based Digital Currencies (NBDC). As NBDCs are piloted within more and less traditional sectors of the economy, these 6 common features are proposed to ensure system integrity, meeting the goal of nature conservation alongside social equity while maintaining a broad space for variations in their designs.
4.1 The System for Environmental and Economic Accounting: blueprint for natural capital accounting

In an advanced monetary system that considers the economic value of nature, the methodologies and standards for natural capital accounting are the system’s foundational bedrock. Much of the groundwork in developing these methods and standards has advanced significantly in the past 10 years. The UN System of Environmental and Economic Accounting (SEEA) has been developed as a framework to take stock of environmental assets and the benefits these assets bring to humanity, as well as to integrate economic data for improved insights on the relationships between the economy and environment. SEEA is a United Nations–hosted project that builds on a similar framework, the System of National Accounts (SNA), which is the internationally accepted standard to compile measurements of economic activity within sovereign nations. The SEEA was designed as a modular approach able to consider various dimensions of natural capital (Water, Energy, Forests, Soils etc) and to adapt to local guidelines and priorities.

We propose that SEEA is an ideal natural capital accounting mechanism to support the “environmental books” behind a new NBDC for three main reasons. First, SEEA is based on a baseline unit of measurement, space and time, upon which environmental data is quantified, allowing comparability on a granular scale, such as 1km²/1 year. A robust NBDC needs to have a globally compatible system for gridding the planet and layering different natural capital value dimensions on top of this spatial grid. Second, SEEA is designed to evolve in a modular way and through experimental approaches. In fact, one of SEEA’s biggest shortcomings is that it has focused on the instrumental value nature gives to humanity and omits the intrinsic value of nature and thus aspects of biodiversity. Yet in the Experimental Environmental Accounting module, these aspects are included and are expected to integrate progressively. Third, it has significant institutional backing from the United Nations, multilateral development banks and the scientific community to consolidate the legitimacy it needs for international adoption. In fact, the SEEA has been implemented by all central banks that have begun to hold environmental accounts. Through the World Bank supported program for Wealth Accounting and the Valuation of Ecosystem Services (WAVES), the central banks of Costa Rica, Colombia, Madagascar, Philippines, Botswana, to name a few, have adopted the SEEA for these records.

The SEEA is still far from perfect when it comes to NBDC implementation. So far, most of the implementations in central banks are as static numbers on spreadsheets within government records. Like greenhouse gas inventories, renewing them has required manual work, which is prone to human error. The opportunity for digitization of SEEA and include methodologies from the digital MRV space would significantly complement the framework. Furthermore, so far, the SEEA has barely addressed methodologies and standards for natural capital accounting in oceans. If they are to succeed at representing nature as a whole, NBDCs need to have a direct incorporation of ocean ecosystems. We explore how these issues of the SEEA can be addressed by the next proposed component.

4.2 Advanced Ecological Credits: dynamic physical-digital linkage

In section 3.2, we discussed how carbon credits have been the primary commodity of environmental markets. However, they are just one part of an ecological credit family that is rapidly expanding and evolving, as traditional environmental market infrastructures are struggling to keep up with the demands of modern buyers of ecological credits. Four distinct pressures are driving the evolution of traditional carbon credits, which are particularly relevant to NBDC.

The first pressure is the need to expand into new methodologies for carbon quantification, such as soil carbon and regenerative agriculture (e.g., the CarbonPlus Grassland methodology), and for new technologies in Carbon Dioxide Removal (e.g., Direct Air Capture or Enhanced Weathering). The second pressure is to include what have been traditionally seen as secondary co–benefits in carbon projects (social and biodiversity aspects) as ecological credits themselves, and the expansion of these beyond land and energy practices, particularly with oceans. The third pressure is the need to digitize the Monitoring, Reporting, and Verification (MRV) methodologies used to reduce the cost of verification and
allow for independent validations such as satellite observations. Finally, ReFi tools are accelerating the modernization of ecological credits, which could improve finance and governance dynamics.

NBDC projects should consider the trend towards advanced ecological credits since not only are these digitalized commodities technically compatible with NBDCs, but their underlying mechanics for validation and issuance can be borrowed by central banks wanting to adopt SEEA frameworks. In this case, advanced ecological credits are issued as units and recorded on the national balance sheet or inventory, rather than freely tradable commodities in voluntary market registries.

The Open Earth Foundation has proposed five key principles for advanced ecological credits, particularly when considering their applications in marine ecosystems. These principles are further proposed for the crediting systems that underpin NBDCs:

1. **Modularity**: This principle entails that the different types of ecological credits or natural capital units (eg. carbon, biodiversity, etc) can be stackable and issued independently, but aligning on a common space & time grid (eg. 1km²/year).

2. **Dynamic**: This principle means that scientific uncertainty regarding the underlying ecological claim of the credit is included in the asset, which can modulate the value of the credit, and its value can change over time with improved data and methodologies. This principle is analogous to including a risk adjustment in the valuation of a financial instrument.

3. **Decentralized**: Verification, accounting, and tokenization of advanced ecological credit is done using global and transparent distributed digital infrastructure to prevent single points of failure.

4. **Digital MRV**: The natural capital accounts and ecological commodities underlying an NBDC should undergo Measurement, Reporting, and Verification (MRV) processes, using methodologies such as remote sensing, internet-of-things sensors, federated assessment models, and verifications carried out by independent third parties with a distinct role for local stewards.

5. **Open**: The digital infrastructure for the issuance of advance credits and even NBDCS, should comply with open standards, open architecture, and open-source software particularly for core protocols and digital consensus.

Of the five principles for advanced ecological credits, the dynamic principle and continuous MRV is perhaps the most important one for NBDC. This is because it ensures a dynamic linkage between the financial instrument (i.e the digital currency) and the underlying ecosystem health. If the natural capital that supports the currency is eroded (eg. deforestation in a forest, or fish stock depletion in oceans), then the value of the currency should drop. Conversely, the instrument’s value would increase after proper investments into the health of the natural reserves. Additionally, embedding uncertainty allows that more experimental ecosystem accounting methodologies can be included yet have a proper dynamic ‘risk adjustment.’ Figure 10 show a summary of the key principled for Advanced Ecological Credits.
4.3 Common Pool Resources and Polycentric Governance

In 2009, Elinor Ostrom became the first woman to receive a Nobel Prize in Economics for her work on how to govern common pool natural resources. She was the first economist to focus on the “commons” and the role of indigenous peoples in effectively managing their common resources for sustainability, to the mutual advantage of all those who depended upon those resources.

Common Pool Resources (CPRs) are pools of resources shared by individuals or groups of appropriators, with the appropriators being the persons that will subtract units of the resources or benefit from the yield of the resource. The concept of CPR is designed to highlight a specific scarcity situation in which appropriators must find strategies to maintain or regenerate the resources that they benefit from, despite the “dilemma” they find themselves in – also known as the “tragedy of the commons”.

Ostrom outlined 8 design principles for the governance of a CPR, which serve as an antidote for the “tragedy of the commons”, undoubtedly the present condition of our global climate and biosphere:

1. Clearly defined group boundaries (and effective exclusion of external un–entitled parties) and the contents of the common pool resource;
2. Appropriation and provision of common resources that are adapted to local conditions;
3. Collective–choice arrangements that allow most resource appropriators to participate in the decision–making process;
4. Effective monitoring by monitors who are part of or accountable to the appropriators;
5. A scale of graduated sanctions for resource appropriators who violate community rules;
6. Mechanisms of conflict resolution that are cheap and of easy access;
7. Self–determination of the community recognized by higher–level authorities;

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8. In the case of larger common-pool resources, organization in the form of multiple layers of
nested enterprises, with small local CPRs at the base level.

The Ostrom CPR framework provides a credible and grounded means for designing governance
mechanisms that are tied to specific ecological, spatial, and cultural conditions. Rather than imposing
uniform methods from “above or afar,” thereby forcing a common denominator of cultural and ecological
norms, polycentrism allows for governance and incentive mechanisms that mirror the circumstances of
the affected peoples and their respective ecologies.

In the parlance of the early discussion of CBDCs, the “backing” of a local natural asset really depends
upon the actions and behaviors of those people who depend upon the sustainability of those natural
resources. Hence, the “banking function” of building reserves, underwriting, and allocating credit is a local
one, dependent upon sustaining a local economy through the actions of those who depend upon and
sustain that local ecology.

This approach represents a very different approach from free market economics and effectively became
its own subfields of “commons economics” and “ecological economics.” Ostrom and her colleagues’
approach to economics and incentives is consistent with those being proposed in this document, and
can be applied to the principles of ReFi and decentralization in the Web3 technology space.

Of relevance to NBDCs is the notion of polycentric and nested governance mechanisms. Ostrom argued
against traditional Western hierarchical governance mechanisms and warned of the dangers of
concentration of control and asserted the subsidiary principle of governance, where those closest to and
most dependent upon the resource should govern it. This framework is especially relevant for the design
of how natural resources are to be governed, financed, and preserved in different localities by different
peoples around the world.

4.4 Complex and Adaptive Socio-Ecological System Framework: factoring local to global
interlinkages

Over time, Ostrom’s ideas were influenced by the principles of the Complexity Sciences and Self-
Organizing systems, and she and her colleagues began to reframe their approach in terms of a Social and
Ecological Systems framework. This new framing emphasized the interdependencies of human and
ecological systems and the need to consider them in their mutual capacity to achieve robustness and
resilience.

Today, research on Complex Adaptive Systems (CAS) and Socio-Ecological System (SES) is well
established in science\textsuperscript{19}, with an emphasis on understanding complex relationships between living
systems, with their environmental surroundings, and the dynamics across spatial and temporal system
scales. The following are four key properties of CAS and SES:

1. A coherent system of biophysical and social factors that regularly interact in
   a resilient, sustained manner;
2. A system that is defined at several spatial, temporal, and organizational scales, which may be
   hierarchically linked;
3. A set of critical resources (natural, socio-economic, and cultural) whose flow and use is regulated
   by a combination of ecological and social systems;
4. A perpetually dynamic, complex system with continuous adaptation

A nature based financial instrument, such as a NBDC, ideally dynamically derives its value from the
underlying natural or living capital. To represent and model that living capital, the dynamics of Complex
CAS in Socio-Ecological context are beneficial at different scales and across scales. The first scale is
related to the project or individual natural capital asset scale. This, for example, refers to the coral reef
that is being restored—in either a marine biodiversity market program or by public conservation actions
within a marine protected area. The second scale of CAS relevant to an NBDC relates to the entire

Bioregion. In the coral example, this scale would be the whole Marine Corridor, such as the “Galapagos Corridor” of the Eastern Tropical Pacific. The third scale is the whole CAS in which this living capital is nested: Earth. The dynamics and interlinkages across the scales are essential to how natural capital stocks and flow are affected in both positive and negative patterns.

4.5 Embedding Life into a computational system of Natural Capital

The current economic and financial system is based on the Newtonian Physics of mechanical, non-living things, which has resulted in treating all things, including living and irreplaceable ones, as fungible and expendable entities that are extracted, priced, and transacted according to the laws of supply and demand. Although this approach generates short-term wealth, it also creates massive and unsustainable negative externalities that threaten the bio-capacity of the planet.

To avoid these pitfalls, a regenerative economic system should adopt the four pillars introduced in the previous section, which impose requirements on the working of an NBDC-driven economic system. Taken together, these pillars inspire a scientifically grounded method to “embed life” into our NBDC system of natural capital, which represents living natural capital. Practically, this involves adopting a method to develop a dynamic ecological accounting system that allows us to:

1. Track nature’s health in its socio-ecological context.
2. Provide a unified metric of health across its multiple scales of socio-ecological organization.

Recent developments in computational biology can provide a complementary, alternative principled and computational basis for representing the living condition of the Earth system and its ecosystems in a way that meets the above two criteria. Computational approaches based on a Bayesian understanding of living behavior, such as Active Inference and the free energy principle\(^\text{20}\), provide the concepts and tools to frame Nature as a continuous learning process that reduces uncertainty about how its ecological states and the pressures imposed by the organisms it hosts are likely to be configured over time. Crucially, these approaches allow us to assess the completeness of different socio-ecological models and the impact of different actions on improving the state of nature by evaluating the “evidence” for each model and what changes in pressures would lead to what results in terms of ecological states. Such “evidence” is a unified measure of the goodness of models. When trained with ecosystem data, such as that which could be made available through the SEEA framework and digital MRV systems, the data patterns become the evidence for ecological states and pressures that are conducive to increased ecosystem health. Active Inference methods are a prime candidate for the modeling of natural capital represented as dynamic ecological credits and debits, for they may allow us to represent and score nature’s health within its socio-ecological context.

The transition from a financial system predicated on models of abiotic mechanisms, reduction, and value extraction to models of generation and valuation of living systems is essential. Nature should not be treated as an infinitely fungible externality, but rather the intent and value of allocating capital should be based on sustaining and increasing the bio-capacity of planet Earth. The goal is not to liquidate a living system into fungible assets but to preserve the capacity of natural, living assets that further generate ecological value. It is a system of value creation and exchange that is predicated on the existential fact that we are part of Nature and that “Her” health is our health.

Non-living, abiotic systems are unbounded in the sense that, other than bare physics, there are no unique constraints or boundaries required to keep them functioning. In contrast, biotic or living systems stay alive by being sentient about their environments and their own actions and observations. They have models that render predictions about their place and actions in their respective niches. Their ability to


stay alive, to successively complete and replicate their respective metabolic cycles over short and long
time scales is their measure of success. Therefore, value among living systems is non-fungible in that
each organism has “invented”/“discovered” its own unique definition of value through its combination of
actions, observations, and predictions, as reflected in its genome and expressed throughout its life cycle.
This stands in contrast to the current paradigm of the pricing mechanism, which is unbounded and treats
all things as fungible and subject to a universal law of supply and demand. Free market models are
indifferent whether something is alive or dead, whether it is indispensable for ecological or even
planetary life. What matters is the spread between buy and sell, and however this is achieved is not part
of the equation.

In conclusion, transitioning to a regenerative economic system that values and preserves natural capital
is crucial for the sustainability of our planet. The current economic system, based on the laws of supply
and demand, treats all things as fungible and expendable, leading to massive negative externalities that
threaten the health of our ecosystem. Instead, we need to adopt a system that recognizes the
interdependence of the economy and the ecosystem and values actions that improve the viability of
both. Active Inference is a promising approach to model the relationship between organisms and their
environment in a way that reflects the complexity of living systems and their socio-ecological contexts.
It has been used to model climate\textsuperscript{21}, behavioral ecological\textsuperscript{22}, evolutionary\textsuperscript{23}, biobehavioral\textsuperscript{24} and cultural\textsuperscript{25}
dynamics within the same integrative framework. By adopting a regenerative economic system and
incorporating Active Inference models, we can shift our mindset towards valuing and preserving natural
capital, which is essential for the health of our planet and our own well-being.


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\textsuperscript{23}Bruineberg, J., Rietveld, E., Parr, T., van Maanen, L., & Friston, K. J. (2018). Free-energy minimization in
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\textsuperscript{24}Friedman, D. A., & Tschantz, A. D. D. (2021). Active inferants: The basis for an active inference framework
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4.6 Issuance of Digital Currencies that embed the integrated framework

The previous 5 components proposed articulate different properties, concepts, and considerations in the design of a currency system based on the health and value of nature. Collectively, they would form a complex and dynamic system designed with a purpose of maintaining living and thriving conditions on this planet. Although implicit throughout the report, we explicitly propose that a successful Nature Based Currency system should be digital (i.e. a NBDC) and leverage Web3 technologies so as to leapfrog alongside the evolution of the internet. While this may well be a bias of the authors, the role of native digitization is proposed for 3 highlighted reasons:

1) **The financial instrument – the NBC – should dynamically adjust to the state and health of nature.** This requires that the underlying natural assets are monitored through increasingly digital, remote and low-cost instruments (e.g. satellites, drones and sensors). Furthermore, the monitoring of nature’s state and health, in the context of an NBC requires a system for trusted accounting. Blockchains, the core aspect of Web3, are essentially a system for trusted sequential accounting. As natural capital accounting becomes the fundamental asset for new monetary systems, a trusted global mechanism for accounting becomes essential.

2) **The NBC proposal also implies an interaction between the currency and a multi-tiered governance context.** This includes different governance participation, from local stewards of living natural capital assets (e.g. Indigenous communities), governance of the underlying monetary policies and models its based upon, and to eventually a collective participation in the governance of the planet that the whole system is based on. As mentioned in the ReFi review section, one of the specific advantages of the Web3 open infrastructure is the creation of decentralized systems that integrate both finance and governance tools and bestow them to the sovereignty of individuals and organizations.

3) **The role of integrated ecological models in the dynamic influence of monetary policy.** This proposed process would also benefit from the web3 opportunities that link currencies or tokens with programmable smart contracts. This is essential because the use of an NBC needs to ensure that it is actively flowing to support conservation and climate action operations and projects. A programmable web3 currency would allow the system to ensure it is used in this context and provide recorded integrity to also prevent misuses and vulnerability to corruption.
5. Dynamics and Opportunities for Architecting NBDC

In Section 1 and 2 of this whitepaper, we laid out the motivation for incorporating the value of Nature as a fundamental capital in our economic and monetary system, and the proper incentive design that ensures humanity has the available and equitable financial capital to address the climate and biodiversity crises. In Section 3 of this whitepaper, we reviewed concepts of central banks and their opportunity with digital currencies (i.e. CBDC), as well as a selection of nature-based instruments and their respective opportunity with the Web3 “ReFi” space. In section 4, we introduced a framework with multiple components to consider in the design and issuance of NBDC. In this section, we combine the components reviewed with the framework proposed to explore system dynamics, opportunities and leverage points within possible designs of NBDC across more and less traditional financial sectors.

As a programmatic process, we identify three distinct approaches for the design and deployment of a NBDC in a spectrum between more and less traditional sectors: 1) the Nature Based Central Bank Digital Currency (NB-CBDC), representing the traditional monetary sector; 2) the non-traditional ReFi NBDC, as a bottom-up and self-governed Web3 enabled community; and 3) an intermediate NBDC, involving private banking, the corporate sector and private environmental reserves. The 6-point framework presented in section 4 is proposed as a common factors to consider across these sectors and the combination of these approaches. The result, illustrated in Figure 11, is a programmatic design process that can be leveraged to support an open architecture exploration for NBDC development.

For this version of the whitepaper, however, we specifically focus on the design opportunities and dynamics for the central banking sector through a NB-CBDCs, which considers the role of private banks and corporations.

Figure 11. Programmatic application of the framework for the design of NBDC across more and less traditional sectors of the economy. Different nature based digital currency archetypes can be designed when combining our proposed framework to the three sectors (central bank, private bank and ReFi) and their combination. The model presented in section 5.1 takes a central bank perspective but incorporates the role of private banks.
5.1 Opportunities for Central Banks: a NB-CBDC with nature as reserve asset in sovereign treasuries

Section 3.1 provided a heuristic overview of how central banks influence the economy through monetary policy, highlighting the economic relations and channels that connect financial and real sectors. Based on this analysis, Section 5 aims to explore how a Nature-Based Central Bank Digital Currency (NB-CBDC) could be leveraged to achieve both central banks' and nature conservation objectives, and how nature could serve as a reserve asset in a national or bioregional treasury supporting financial capital for climate and conservation action, particularly in the Global South.

To start answering these questions, we map some of the key mechanics of central banks presented in Section 3.1 onto an economic system where a NB-CBDC would circulate, and examine how the 6-point framework from Section 4 could apply to it. We acknowledge that a serious discussion on the implementation of a NB-CBDC should address many more issues in greater detail, and that its implementation may introduce significant distortions that should be modelled and simulated. However, our goal here is to speculate on the dynamic that could arise under an economy that uses a NB-CBDC for certain activities, and to highlight some opportunities for its implementation within such a system. Therefore, we begin by exploring what it would mean for a CBDC to be 'nature-based' or 'nature-backed'.

5.1.1 Exploring the meanings of “backing” by nature

This section explores the potential for a nature-based CBDC that would be linked to the state and well-being of the natural environment. This "programmable money" could be used to fund conservation, restoration, and climate initiatives. We begin by examining the idea of Nature as a reserve asset that could “back” a currency.

The term "backing" has various meanings (see Figure 3). For example, a unit "A," such as currency, can be said to be backed by a unit of "B," such as precious metals like gold or silver, if the value of "A" is based on the available quantity of "B" and if "B" can be traded at a fixed price against "A." This was the case with many Western currencies during the era of the "gold standard". In this context, "backed by" means "exchangeable for."

Another related meaning of backing in the realm of securities is the notion of backing as "collateralizing." In this case, B (e.g., a mortgage) is backed by or collateralized by C (e.g., a house) if the creditor, who has given some "A" (e.g., money) to the debtor to acquire her house, can access "C" if the debtor fails to repay the "A" (with interest). In this scenario, backing also means "exchangeable for," although the exchangeability depends more on the ability of the state to enforce the law.

The value of the backed entity in these cases depends on the state acting as the guarantor of "exchangeability." "Backing as exchangeability" assumes that there should always be some entity available for exchange (e.g., the house or the precious metal). This further assumes that the value of the backed entity rests on the transferability of property rights and the ability to extract or displace the backing entity (e.g., extracting, selling, and delivering the gold or selling the house).

The concept of backing as exchangeability and collateral may not align with the regenerative function of a nature-based CBDC, or at least would be highly problematic given collateral assets need to be "liquidated." If nature becomes a collateral asset in its traditional sense, then in the case of a default, liquidation would allow creditors to appropriate nature and extract its value. This could be prevented if the underlying collateral land is a private reserve with enough legal protection in its tenure to prevent such activity, such as a Conservation Land Trust.

A third meaning of backing applies to fiat currencies. The value of the backed entity in this case rests on the state’s ability to act as the guarantor of the "extinguishment of a debt." In a fiat system, "A" (e.g., the

currency) is not backed by another entity “B” for which it could be exchanged. Instead, “A” is backed by the fact that, by law, one cannot refuse “A” as a means of payment (i.e., A is a “legal tender”). This gives the state the ability to modulate economic activity more directly, for it allows public organizations (e.g., a central bank) to inject “means of payments” into the economy without tying those means of payment to some other existing entities (e.g., precious metal).

This third meaning of “backing by the law” could be used to “base” the proposed nature-based CBDC. A CBDC backed by the law would allow the state to make economic decisions within the limit of its mandate that aren’t dependent on the state of a tier backing entity (e.g., based on the global gold supply).

Such a meaning of “backing by the law” is one of the concepts of backing that could be included to “base” the proposed Nature Based Central Bank Digital Currency (NB-CBDC). A NB-CBDC backed by the law would give the state the ability to make economic decisions targeting sectors of the economy leveraging the NB-CBDC. This high centrality of the state may have its advantages and disadvantage. To ensure that the rule of law applies irrespective of any political agenda, it may be necessary to incorporate the “Right of Nature” into the constitution. Many countries, including Ecuador, Colombia, Panama, and New Zealand, have already incorporated aspects of the Rights of Nature into their constitutions.

One potential solution is to combine the backing by law with tangible reserve assets that serve as collateral, but cannot be liquidated in the traditional sense. These reserve assets must be preserved in their natural state. Figure 12 illustrates this hybrid opportunity for the NBDC.

Overall, combining the backing by law with tangible reserve assets, along with the incorporation of the Right of Nature into the constitution, can help ensure that the NB-CBDC is used in a responsible and sustainable manner.

Figure 12. Hybrid backing of a currency with nature assets and policy. The diagram illustrates how a proposed currency could be backed by both assets and policy, considering collateral assets (e.g., private land reserves and instruments), public assets like national parks, and the modelled linkage of the local environmental services to the global ecological state, whilst keeping a policy that the assets value is derived from it being “alive,” (i.e. liquidation and extraction of a standing forest will provide a much lower value) and nature having an intrinsic right.
To envision an economy utilizing NB-CBDC as legal tender, it’s essential to consider the economic channels through which it would circulate and how its liquidity would impact economic activity and the state of nature. Additionally, State institutions need to determine the computational model that informs their decision-making process regarding the modulation of NB-CBDC supply in the economy. The next two subsections delve into these crucial aspects.

5.1.2 Illustrative example of a model economy for NB-CBDCs

This subsection explores how NB-CBDCs can help a country secure the financial capital necessary to protect and restore nature, such as achieving a 30% conservation of land and oceans by 2030. We examine how a central bank can use this currency to steer the economy toward this goal while maintaining its own mandate and legacy responsibilities. We further consider what economic channels or levers an economy should have so that the liquidity of NB-CBDC can influence economic actors to ensure a thriving nature. We also explore how the NB-CBDC issuance can support the costs of public and private conservation, such as paying for park rangers, advanced digital monitoring, and restoration activities, as well as infrastructure and operating costs required to maintain high ecological health of key ocean and land regions.

To illustrate how NB-CBDC can be leveraged for conservation and climate action, we present a model economy endowed with economic channels through which NB-CBDC can circulate. This model enables the purchase of claimable advanced ecological credits or EcoCredits, and environmental securities such as Nature Treasury Bills and Green Bonds. EcoCredits are verified records of environmental health improvements, including national inventory records, and credits that are produced or used by private banks and firms to meet environmental goals. They are eventually retired or recorded under a national inventory.

The proposed model economy involves at least five key actors:

1. A National Treasury entity able to issue NB-CBDC as well as Treasury Bills, Bonds and Notes, in sync with a National Inventory of Environmental Accounting (i.e. reserve nature assets), and a National MRV system that independently tracks the states and balances of these inventories.
2. A Central Bank that manages the NB-CBDC under monetary policy, regulating liquidity in the economy and able to modulate interest rates associated with it.
3. Private Banks able to lend NB-CBDC to firms.
4. Private entities, such as Corporations and Investment Funds, which have ESG and SDG targets (either regulated or not) and can use NB-CBDC to reach these targets through both In-Setting (i.e. improvement of internal operations) and Off-Setting (i.e. improvements outside the firm’s operations);
5. Private entities such as Project Developers from the natural capital sector undertaking Conservation and Climate Action projects that produce EcoCredits and/or issue environmental debt instruments such as Green Bonds.

The basic assumptions of our model are that:

A. NB-CBDCs are legal tenders (i.e. valid means of payment) within the domain of EcoCredits and Environmental securities (eg. TBill and GreenBonds).
B. Private firms can borrow NB-CBDCs to finance internal (i.e In-Setting) and external conservation and climate actions that produce EcoCredits, which are used to take stock of their progress to achieve ESG and SDG targets.
C. Entities such as central banks can manage the issued NB-CBDCs, hold NB-CBDC and EcoCredit accounts, and pay interests on holdings in those accounts.
D. EcoCredits represent a broad category of verified ecological outcomes, either as tradeable assets (eg. environmental commodities) and/or certified records of internal environmental improvements. These can include, but are not limited to mitigation outcomes, carbon credits, biodiversity credits, marine ecosystem credits, renewable energy certificates, In-Setting certifications (eg. internal emission reductions) and others.
E. A National MRV can be centralized or decentralized (i.e. with multiple MRV agents) and keep track of the state of national Environmental Accounts, including GHG inventories, land and ocean ecological inventories, water inventories etc. Inventories are designed with nested accounting, meaning private targets, actions and accounting are visible and roll-up jurisdictionally to the national level.

F. A Nature Treasury Bill is issued to provide financial capital to the national, subnational and ministerial government (e.g. Environment Ministry) to specifically support costs associated to conservation and climate actions.

G. The NB-CBDC can operate as a parallel currency to the existing national currency or CBDC, and be exchanged when needed. The model, however, does not prevent a design where the existing currency or CBDC is used instead of a dedicated NB-CBDC. In this case, extra considerations would have to be in place to prevent volatility of the national currency.

In our economy model, central banks can use Open Market Operations (OMO) and interest payments on accounts to regulate economic activity and EcoCredit production in accordance with national conservation and climate targets. There are two key aspects to this:

1. T-bills are a guaranteed investment, while EcoCredits gain economic value by being retired to meet private and public nature and climate targets, increasing their demand.
2. To create incentives for retired EcoCredits, private entities with the technical infrastructure and legal capacity to freeze and account for EcoCredits (such as private banks and environmental registries) can deposit and earn interest on EcoCredits. They can also lend NB-CBDC to other entities for internal environmental actions or to purchase EcoCredits for retirement.

The dynamics outlined above enable central banks to regulate the circulation of NB-CBDCs, which can help achieve environmental goals by incentivizing the production of EcoCredits (i.e., verified environmental outcomes). The demand for EcoCredits would be linked to economic activity and accountability regarding environmental goals (e.g., firms' efforts to reduce their carbon footprint or offset externalities). The production of EcoCredits, in turn, would encourage the preservation and restoration of ecosystems and the achievement of climate goals. This process is illustrated in Figure 13 and could unfold as follows:

Corporations and investment funds would seek to borrow NB-CBDCs to finance internal environmental performance improvements (e.g., "In-Setting Actions" that are recorded), purchase external EcoCredits, or invest in financial instruments such as T-Bills and Green Bonds on the open market. This would enable them to meet ESG requirements and specific environmental goals, such as Net Zero pledges. After purchasing or creating EcoCredits through verified outcomes in their operations, firms would have to retire these credits (i.e., lock them into the accounting system) by depositing them in an environmental registry account or bank.

Private banks would be responsible for issuing NB-CBDC loans to firms and could earn interest on these loans. In partnership with an environmental registry, private banks would monitor the retirement of EcoCredits or their registration as environmental records, which central banks and the national inventory could also review.

Central banks would have many levers to influence firms' economic and environmental activity and associated externalities. For example, they could change the NB-CBDC allocation that private banks have access to for their subsequent loans to firms. They could also buy and sell EcoCredits or Nature T-Bills on the open market to change the liquidity of NB-CBDC in the economy. This would affect the NB-CBDC liquidity of private banks and therefore the interest rate that they charge each other for NB-CBDC, and ultimately the interest rate they would apply to private NB-CBDC loans. Central banks could also change the reserve requirements of NB-CBDC in private banks to have a similar effect. These processes should be carried out in concert with the National Treasury, which issues the currency and deals with the reserve assets, and the state of its inventories, which are used to track progress towards environmental goals.
Figure 13. National economy that leverages a nature-based CBDC to increase ecosystem health. A. Corporations borrow NB-CBDC to both finance In-Setting actions and buy EcoCredits (EC) on the open market to offset their remaining emissions and meet their ESG targets. To claim the benefits of the EC, firms must retire their EC to a private bank.
account or environmental registry. **B. Private banks** can hold retired (EC at the central bank, and can earn interests on the holdings. They may be legally obliged to respect a reserve requirement of NB-CBDC (assuming that the NB-CBDC is token-based) to always allow the purchasing of EC. This may lead to a system of NB-CBDC lending and borrowing among private banks. Private banks can also buy EC on the open market and retire them themselves. **C. Central banks** can change the interest on the private banks’ EC account to incentivize NB-CBDC lending, and it can purchase EC on the open market. The private bank can also change the reserve requirement on NB-CBDC to incentivize private banks to lend more NB-CBDC. **Eco-credits producers** are represented by both public and private sectors and include indigenous nations. The EC producers receive the NBCBDC by selling securities, EC or as payments for ecosystem services, based on their actions and the independent MRV that verified their claims. As **ecosystem health** increases, its represented as accounted records in the National Environmental Inventory (eg. compiled by the environment ministry), and as assets held by the National Treasury.

Our proposed model economy empowers central banks to influence economic activity across all sectors, including the natural capital sector, by stimulating or reducing the production and purchase of EcoCredits. This enables both public and private conservation and climate actions, such as funding national parks and conservation areas, as well as private sector projects. We aim to bring nature onto the balance sheets of financial institutions through independent environmental registry accounts held at the central bank or the national inventory, monitored by the central bank or private banks.

In this regenerative economy, central banks have a crucial role in generating positive global environmental outcomes by issuing currency to finance conservation and climate projects that benefit local and global ecology. This goes beyond the traditional mandates of central banks, which usually focus on taming inflation or maximizing economic output.

However, achieving environmental outcomes is not limited to local benefits and services, given the interconnectedness of carbon sequestration, biodiversity restoration, and ocean protection. Therefore, models that quantify the environmental services in the National Inventory/Treasury should consider the nested nature of Complex Adaptive Systems and evaluate the local–global linkages.

To inform their monetary policy decisions, central banks need to have the right economic and environmental modeling tools to dynamically quantify and value local nature assets that produce global environmental services.

5.1.3 Bioeconomic models for monetary policies targeting NBCBDC liquidity

To determine how central banks can leverage NB–CBDCs and ESG/SDG corporate capital to steer the economy, we need to explore how central banks would decide on NB–CBDC related monetary policies. To forecast the effect of traditional monetary policies, central banks use mathematical models that map out the relationship between different actors in the economy and their effect on key variables such as supply and demand. One common type of model used by central banks is the Dynamic Stochastic General Equilibrium (DSGE) model\(^\text{27}\).

DSGE models allow central banks to predict how actors’ choices and expectations will impact key variables over time. A basic DSGE model includes three variables: demand, supply, and monetary policy. Each variable is described by functions that detail the microeconomic behavior of actors that influence those variables, including households, firms, and central banks\(^\text{28}\). These models also factor in economic “shocks,” which are exogenous events that will influence other variables in the model.

Environmental or ecological perturbations caused by climate change are an important source of exogenous shocks. However, by transforming these shocks into known variables, central banks can better predict their impact on the overall economy. Planetary temperature is one such heuristic that allows us to prevent adverse climatic events by reducing emissions, externalities, and integrating economic activity with ecological demands. This type of behavior can be modulated using NB–CBDC related policies.


To achieve this, central banks need access to economic models that factor in environmental shocks as variables upon which they can act indirectly, such as by influencing NB–CBDC liquidity. These models may be mixed models using standard DSGE models to forecast the dynamic relation between supply, demand, and monetary policy, while also considering environmental fluctuation variables whose value may be computed using alternative models.

One possible alternative model is the Active Inference Model described in section 4.5. These models provide multiscale descriptions of the complex relationship between biobehavior, ecological, and social dynamics, allowing us to predict the shocks that changes in those ensembles may entail in an economy. Simulation models built on top of this framework may allow for the forecasting of environmental fluctuations that would act as shocks in an economy.

In response to environmental shocks, central banks may decide to apply the various NB–CBDC based tools at their disposal to slow down economic development and EcoCredits production. By integrating these policies with environmental goals, central banks can steer the economy towards reaching targets on economic output, employment, interest rates, inflation, and climate-related targets.
Figure 14. Incorporation of an ecological economic model as a tool informing central bank monetary policy and its transmission to the economy. The diagram extends from figure 5, which outlines the transmission process from central bank monetary policy to the economy, adding an integrated computational bioeconomic model that informs policy and tracks its influence on the national Natural sector and its linkage to global Earth system state.

5.2 Limitations, concerns, and considerations for the NB-CBDC model
The model economy presented in section 5.1 is the result of an ideation and first iteration for how a NB-CBDC (nature-based Central Bank Digital Currency) could be designed in the context of making nature a fundamental asset within our economy and empower environmentally rich countries in the Global South with a mechanism to create the financial capital they need. Furthermore, this ideation of a nature-based currency represents an intentional exploration from the perspective of the central banking sector, which is one of the three sectors of the economy presented at the beginning of section 5 – divided in terms of more or less conventional levels.
Having illustrated this first iteration of a model, we can highlight specific limitations and concerns about this proposal to consider for open stakeholder discussions as well as next design iterations:

A main limitation to envisioning an effective NB–CBDC relates to the level of institutionalization and global acceptance of such a currency system. Because economic systems and the instruments that circulate in them must, to some extent, be recognized by the international community (eg. for legal tender), one must consider how such a NB–CBDC system may be implemented, recognized or accepted by multiple countries. One possibility to address the lack of tender by other countries, is to work on the design of such instruments alongside the supranational institutions that inform and influence the central banking sector, for example the Bank of International Settlements. Another possibility and opportunity may be to develop such a system for a bioregion rather than a single nation state. For example, a NB–CBDC initiative could be led by an environmentally innovative country like Costa Rica as part of a network with Panama, Colombia, and Ecuador around the Galapagos Marine Corridor (i.e. CMAR), allowing multiple countries to adopt the NB–CBDC system, which they may use to finance the collective conservation actions required. Under this model, the central banks of the countries belonging to the bioregion could create banking linkages and establish a Bioregional inventory that connects national ones. This opportunity not only helps multiple countries accept a common financial instrument, but it also addresses the limitations of having political boundaries (i.e. country borders) determine the conservation finance options for natural ecosystems, biodiversity corridors and indigenous communities that don’t follow the geo political rationale.

Beyond limitations, one of the primary concerns that sparks when reviewing the proposed NB–CBDC model economy relates to the level of centrality of the Central Bank on environmental policy. Central banks are by no means equipped to be experts in climate and conservation matters, yet in this model they become a key central regulators of on-the-ground environmental actions via the distribution of financial capital. What restrictions or balancing influences need to be added to the NB–CBDC system to ensure environmental integrity, social equity and effective economic management? In the illustrated system, the ‘bioeconomic’ computational model can include these considerations when influencing the central bank’s monetary policy based on the result of robust computational and algorithmic assessment. However, this would then give a high level of centrality to the model and algorithm.

A second point of concern relates to the susceptibility of having market forces (often irrational and partial) determine the value of nature. As pointed out at the beginning of the document, supply and demand market dynamics are incomplete for the valuation of arguably priceless assets such as coral reefs or primary tropical rainforests. Volatility is also a major concern if the NB–CBDC is openly traded, creating opportunities for “boom & bust” market episodes that are common in stock or crypto asset trading.

A final major concern relates to unintended consequences even after the system is well deployed, with funds funneled directly to active projects on ground. Here the concern is that while the conservation and climate projects are being developed, the overall national goal (eg. achieving a 1.5°C consistent climate transition) is not being achieved, or that the funds are funneled only to privileged corporate project developers with economies of scale as opposed to the immediate local stakeholders like indigenous populations. Both issues should be considered when designing the digital rules for how NB–CBDCs can be distributed and to whom, eg. tracking the stakeholder beneficiaries, as well as including feedback dynamics of the overall state of goal achievement into the determination of priorities of funded projects.

Finally, a critical future consideration that emerges while reviewing the proposed system is that of creating a digital simulation environment, where the system can be tested computationally (eg. with agent-based models, self-learning artificial intelligence and game engines that support tokenomics) and in pilots with real stakeholder co-designing the process. The benefit of simulating the system beforehand is that the same simulation engine can then be used as part of the ecological economic model used by the Central Bank to inform NB–CBDC monetary policy, and constantly provide feedback on potential unintended consequences as its being deployed.
6. Summary and conclusions

The goal of this whitepaper was to explore proposals and design principles for novel financial instruments and currency systems that would benefit emerging economies with an advanced monetary system that seeks to align with climate and environmental imperatives. Crucially, the vision we have outlined in this paper should not be viewed as presenting the ideal or ultimate model. Our goal was to lay the systems thinking groundwork on an important, and perhaps inevitable topic, while also developing a mockup or “thought experiment” that gives some framing to allow the reader to test intuitions about how we, as a planetary system, could one day fully integrate nature into a unified economic and biological reality. At best, the approach presented here should be taken as a benchmark against which one could compare future iterations of a vision for nature–based monetary systems. In fact, each country or bioregion could take different features from our vision and use it as a playbook to design their own nature–based monetary solutions.

After having motivated our project by highlighting issues in global north–south relations and extractive economies (section 2), we have explored how traditional institutions like central banking systems and nontraditional financial systems such as those of Regenerative Finance (ReFi) in Web3 economy (section 3) could be integrated into an advance nature based monetary system. We have suggested that such integration could be achieved through the development and circulation of, broadly, Nature Based Digital Currencies (NBDC) whose design would conform to a 6–parts framework to guarantee the ecological soundness of such currencies (section 4). Focusing our efforts, we then explored how NBDCs can be liabilities of central banks – i.e. as Nature Based Central Bank Digital Currencies (NB–CBDC) – and how they would circulate in a model economy to help private and public actors reach their environmental goal (section 5).

In this “thought experiment” (section 5.1.2), private actors such as firms would seek to finance internal environmental performance improvements (i.e. InSetting Actions) through the borrowing of NB–CBDC, and compensate external impacts with the purchase and retirement of advanced ecological credits (EcoCredits), presented here as a broad category of verified records of environmental outcomes. Central banks would seek to stabilize the economy by performing market operations over EcoCredits, thereby improving their ability to “green” steer the economy, under the assumption that the production of EcoCredits become the accepted way to verify improved environmental performance among private actors of the economy. The net economic effect of using the NB–CBDC system is to, effectively, put “nature onto the balance sheet” of public institutions and firms, so they can now factor into their economic decisions, “living” financial assets such as dynamic EcoCredits. An intended consequence is that in such a bioeconomy – i.e., an economy that puts the biological condition of Nature on the balance sheet of its actors, countries who are the stewards of most of planet Earth’s natural wealth will get a chance to be meaningfully integrated to the global economic and political landscape. In such a bioeconomy, instead of being the target of extraction and exploitation, these countries become stewards of our global natural treasure and have the financial capital and incentives needed to protect, thereby promising some rebalancing of global north–south disparities. Of course, there is much more to unpack with respect to the vision that we have developed in this white paper. The NB–CBDC design, even at such an early stage, can appear problematic as its laid out in section 5.1.4.

We conclude this paper with a brief discussion of the missing parts and possible drawbacks of our overall vision for an advanced monetary system.

First, our design vision has not focused explicitly on the role of the nontraditional economic sectors, nor in environmental areas that are outside traditional political and legal systems. We have highlighted some applications of ReFi that would matter to an advanced nature based monetary system, but we did not
specify how ReFi could be leveraged in the context of a NB–CBDC. ReFi, understood as a set of Web3 applications, could, for instance, function as bottom-up, open source and decentralized institutions for the creation of a global NBDC system. Global level coordination for the protection of world regions that lack adequate legal protection such as the high seas is difficult to achieve because such regions exist beyond national jurisdictions. The new UN High Seas Treaty following the Global Biodiversity Framework is certainly a breakthrough in having a global agreement on this area, but how to bring it to effect is still to be designed and decided. Because ReFi protocols enable the establishment of economic and financial regimes beyond the jurisdictional boundaries of nations, these could be used to build economic systems over Non-Jurisdictional Natural Capital such as that of the high sea. This could steer incentives for economic activities in those regions towards nature protection and regeneration.

Second, we did not discuss the issues relating to individual citizens and their privacy under a central bank NB–CBDC. In fact, we only articulated a ‘wholesale’ NB–CBDC model operated between central banks, private banks, and corporations. Without intermediaries like private banks, a direct NB–CBDC that would operate at the level of retail could allow central banks to influence economic behavior at the individual level. If a NB–CBDC is used by individuals, say, for the purchasing of goods whose value may be partly given by their ecological footprint (e.g. buying a car in local currency and paying a green tax in NB–CBDC, a central bank with the power to issue retail NB–CBDC would be in a position to target and influence consumer behavior at its root. One should wonder if such a “direct” power should be given to a public institution such as a central bank. Adding such a tool to the kit of central banks would extend their reach within the domain of governmental power. For instance, issuing monetary policy with such a retail NB–CBDC would mimic fiscal policies, and should thus require a higher level of coordination between governments and central banks. Such a coordination may be achieved if fiscal and monetary policies rest on a same integrative model such as the DESG and active inference model hinted at above, tracking the relation between economic and ecological dynamics. The same reflection applies to the issue of the centralization of powers raised in section 5.1.4.

Third, one should note that building financial instruments out of nature, to consolidate nature as a precious asset worth protecting, may have both positive and negative effects from market dynamics. Compared to many securities, nature has a fundamental intrinsic value that cannot go negative, and so a nature–based instrument should never be worth nothing or less than nothing. If such a nature–based instrument is endowed with some dynamics that allows its underlying physical reality to keep its price in check (e.g., the uncertainty metric of dynamics ecological credit), one could mitigate risks of market irrationality. The price of nature–based instruments should ideally track their fundamental value, but that may be hard to harmonize globally, across other currencies and subjective perceptions of Nature. Because there will always be some correlation and mutual influence between markets, and because in principle there should be no ceiling value to nature, it may be possible that markets can overvalue nature–based instruments. And although the realization of this would never lead to “natural bankruptcies”, it could nonetheless fatally hurt the system built on top of such instruments, or stop benefiting the primary stakeholders (e.g., the EcoCredit producers and/or indigenous nations) by being captured. This is particularly concerning with market bubble incidents as mentioned in section 5.1.4. Thus, having a clear understanding of how a nature–based financial, economic and monetary system would intertwine with the classical system is of the utmost importance.

Despite these and certainly many more hurdles ahead, we believe that researching and acting on a vision like that outlined in this paper is central to innovating on climate and biodiversity finance, rethinking our

collective concept of wealth, and revisiting its current geopolitical distribution. Designing and building infrastructure for advanced monetary and financial systems, which can digitally link a financial instrument to the dynamic ecological state of nature, are important activities to consider under international policy frameworks, such as the UNFCCC Paris Agreement and the Montreal GBF. Our hope with our illustrative example of a nature-based currency economy is that, by showcasing a highly innovative model—that is technologically attainable with current emerging digital technology—we can inspire collaborative efforts in design and implementing versions of our proposed vision for embedding nature in our economic system. This programmatic whitepaper, in the spirit of its open innovation process, should be kept as a living document across different variations and iterations of NBDC design.