The Internet of Impact

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This white paper describes the purpose and design of an Internet of Impact. We explain how this blockchain-based Internet will become an essential digital infrastructure for Sustainable Decentralised Finance (Sustainable DeFi) and Impact Data. To finance and verify the changes that are urgently needed in the social, environmental and economic state of the world, and to mitigate impacts of the climate crisis.

Summary

ixo is leading the development of an Internet of Impact. This essential digital infrastructure is formed by interconnecting globally and locally distributed blockchain networks that implement the ixo protocol. Through which Sustainable Decentralised Finance (Sustainable DeFi) and Impact Verification applications can be built and deployed at Internet scale.

This new Internet overcomes the limitations of legacy Web 2.0 Internets, by being stateful, graph-based, programmable and trustworthy. It is also verifiably carbon-neutral.

The ixo protocol defines a new open standard for producing verifiable claims about changes in the state of the world. Which are the basis for impact creators to mint non-fungible (NFT) Impact Tokens.

The ixo protocol applies the latest decentralised web (W3C) standards for linked-data (JSON-LD), decentralised identifiers (DIDs) and verifiable credentials (VCs). We have created the Interchain Standard for next-generation non-fungible tokens (NFTs) and verifiable metadata.

Sustainable Decentralised Finance (Sustainable DeFi) and Impact Verification applications built on the Internet of Impact have the potential to fundamentally change the state of the world. By transforming how we finance, implement, measure, value and create markets for sustainable impact. Which is relevant to all forms of capital flowing into social, environmental and economic development, as well as Climate Finance and Carbon markets.

Community currencies implemented through the Internet of Impact can drive outcomes towards local social and economic development goals, in ways that are inclusive, locally governed, low-risk and sustainable. With great potential to innovate new use-cases, new forms of economic production, new types of incentive schemes, new investment mechanisms, and new economic models for community sustainability and local resilience.

Internet of Impact networks will give people everywhere access to the trustworthy information and financial tools they need, to invest and spend their money in more sustainable ways, and to hold public finance accountable. As mandated by the *UN Task Force on Digital Finance for the Sustainable Development Goals*.

Impact Tokens are units of value created through the Internet of Impact. Each Impact Token represents a real-world outcome state that people care about, are willing to invest in, work towards, or spend their money on. Impact tokens will become the new standard for measuring, verifying, reporting and valuing impacts through marketplace mechanisms.

Tokenizing verified outcome states through the ixo protocol transforms traditional certificate-based outcome representations, such as Carbon Emission Reduction Certificates, Education Certificates, Immunization Certificates, Biodiversity Certificates, or any other certified outcome state, into tradable and investible digital assets. Which are backed by data assets and verification proofs, with embedded executable rights.

Programmable Capital applications can be built using the crypto-economic mechanisms and Impact Graph provided by the Internet of Impact. Alphabonds are are the world's first cybernetic Sustainable DeFi mechanism for results-based financing of outcome

states, and to produce Impact Tokens, with risk-adjusted token bonding.

Alphabonds adaptively bond real-world state changes to blockchain state-changes, through trusted information-feedback loops, which algorithmically update a bond's share token prices and supply, in response to real-world risk signals, which can be derived from any trusted oracle data source.

Alphabonds have been engineered and scientifically validated to deliver *Impact Alpha* – above market average – financial returns and sustainable impact results.

The Alphabond design also offers a novel internal prediction market mechanism for deriving risk signals directly from the convictions of bond token-holders over time. Which transforms stakeholders into a collective intelligence oracle and puts people in the loop of development financing processes.

This versatile crypto-economic primitive can be configured into a diverse range of sustainable DeFi applications, including tokenized Impact Bonds, Green Bonds, Use of Proceeds Bonds, Insurance Bonds, Innovation Bonds, Governance Bonds, and Community Currency Bonds.

The Internet of Impact Hub is a global network of proof-of-stake ixo protocol blockchain validator nodes, operated by leading development agencies and impact market-makers. This interconnects autonomous Impact Zone networks using the Inter-Blockchain Communication Protocol (IBC), which connects through to the Cosmos Hub and Internet of Blockchains, with bridges into other networks, such as Ethereum and Bitcoin.

Prediction Oracles are a new type of service delivery mechanism for processing and enriching impact claims. Data-driven specialised services perform event-driven tasks, such as verifying claims, prescribing and personalising interventions, predicting outcomes, detecting threats and preventing risks.

Prediction Oracles integrate external data sources, such as satellite imagery and IoT devices, to transform claims into digital credential certificates, such as Renewable Energy Certificates.

At the application layer, ixo provides new tools, market access and data for both legacy and AI-augmented verification services to improve the performance and reach of their proofing and prediction methods. Offering investors and project implementers everywhere more affordable and better access to specialised expertise, intelligent decision-support and trustworthy impact verification.

"A digital immune system for humanity" describes the bio-mimetic design of the Internet of Impact. Which enables us to locally sense and respond to sustainability threats or opportunities, with mechanisms to coordinate, signal and amplify interventions. Building innate intelligence and enduring memory to replicate what works, evolve, and respond more effectively in future.

The tokenized impact economy built on the Internet of Impact has potential to grow rapidly through marketplaces that are already worth trillions of dollars.

1 Sustainable Digital Finance

The Internet of Impact provides the infrastructure for the next generation of sustainable digital finance.

1.1 DeFi

Decentralised Finance (DeFi) has successfully demonstrated that traditional financial instruments can be reinvented and deployed at Internet scale for anyone to use, replicate and rapidly evolve.

Tokenized assets worth billions of dollars are now staked in or flowing through DeFi protocols.

1.2 Sustainable DeFi

Sustainable DeFi further advances the concept of DeFi, by embedding DeFi mechanisms, together with claims verification, into a stateful, graph-based, programmable and trustworthy blockchain infrastructure.

A key differentiator, in comparison with most DeFi applications to-date, is that Sustainable DeFi crypto-economic mechanisms are deterministically driven by extrinsic real-world state changes.

This is an extremely powerful concept, because what happens in the real-world is what matters.

Sustainable DeFi responds to changes in the state of the world by autonomously triggering events — such as price changes, or payment transactions, which change the state of a blockchain.

An even more powerful idea, which leads from this, is that changes in the state of a blockchain can bring about changes in the state of the real world.

Human behaviours are substantially influenced by blockchain state-changes when:

- People receive the financial incentive of being paid for results.
- The current state of progress towards shared goals is both visible and accountable to all stakeholders.
- Trust is elevated by making claims verifiable, with independently verified data as evidence.

Sustainable DeFi can therefore better align people's incentives to work together, invest their money into outcomes they collectively care about, pool available resources, and coordinate their actions to achieve the future-state outcomes in which they all have a stake.

For example, an immunization campaign can trigger an Outcome Payment to investors and implementers, when a target population coverage threshold has been achieved.

Sustainable DeFi requires trustworthy interfaces between the real-world and blockchain state-machines, which are bound to a series of state-changes over time, recorded in an ordered, directed acyclic graph. With reliable signalling mechanisms and economic stakes, bonded to reality.

The Internet of Impact provides the mechanisms, services, data and economic platform with which to

build the next generation of sustainable digital finance ecosystems.

1.3 Community Currencies

Tokenized community currency systems can promote inclusive local socio-economic growth and resilience, by enabling communities to achieve greater self-sufficiency.

"Community currencies are a form of money and credit standard similar to Currency Boards. A Currency Board is a reduced, rule-based monetary policy that operates as if in 'auto-pilot' mode, because there is no option to provide credit to the national government, commercial banks or state-owned enterprises." [2]

Blockchain mechanisms enable community currencies to be implemented as systems which are locally owned and governed.

Using the Internet of Impact Sustainable DeFi mechanisms and Impact Graph enables community currency systems to be implemented in ways that adaptively respond to changes in the state of the real world state, to direct economic growth towards sustainability outcomes.

This aligns the incentives of community currency token-holders to collectively work towards desired outcome states in which they all have a stake and this can promote local solutions to local problems.

Token Bonding Curve mechanisms, such as Alphabonds, provide an automated mechanism for issuing and managing the treasury of community currencies in a decentralized and sovereign way. These mechanisms allow for the currency supply to expand—or contract—in response to real economic growth, making this sustainable and non-inflationary.

As an example, an Alphabond can be configured to direct Outcome Payments into a community currency reserve, to incentivise and reward participants for achieving shared development goals—such as a community immunisation coverage target—which increases the value of the community currency token and makes everyone richer.

The results of community currency transactions and systems can be measured using verifiable Impact Claims.

Impact Tokens can be produced to represent the various forms of value generated by a community for financing outcomes.

The Internet of Impact connects community currencies by linking automated market-maker reserves, for local economies to trade with each other, into regional economies or within global digital marketplaces for products, services and capital.

Community currency systems have many possible configurations and use-case applications.

Fractional reserve community currencies, which can have a fiat reserve—using a stable fiat-backed token—multiply the local currency supply, whilst also enabling

participants to enter or exit the reserve pool with their national currency. Which enables communities to transact both within their internal local economy and within the national economy.

This is compelling alternative for cash-transfer programs, compared with blunt instruments such as government Stimulus Cheques.

By linking local currency tokens through automated market-makers that share reserve pools, currencies can be exchanged across communities, for participants to transact across marketplaces.

The pioneering work of Grassroots Economics in East Africa demonstrates how Community Inclusion Currencies provide an efficient and scalable way of implementing cash transfers to communities in need—which was particularly evident during the 2020 economic crisis resulting from the Covid-19 Pandemic. [3]

Tokenized Community Currency mechanisms can also be used for Universal Basic Impact schemes, which are gaining traction in many different economic contexts— including government-sponsored social welfare programs in developed countries.

1.4 Potential of Sustainable DeFi

Sustainable DeFi enables capital to be continuously programmed to achieve future outcome states in capital-efficient, deterministic, risk-adjusting ways, at a decentralised level.

It is conceivable that Sustainable DeFi, implemented at Internet scale, could fundamentally change how capital markets operate. By providing more efficient and accountable financing mechanisms, with trusted data, local feedback loops and economic incentives, to optimise both the financial results and impacts of creating and using financial capital in more sustainable ways.

The crypto-economic mechanisms powering community currencies, combined with the configurable state-space of the Internet of Impact Graph, holds great potential for socio-economic innovation that could lead to entirely new models of sustainable economy and social transformation.

Sustainable DeFi could become a critical enabler for proven interventions to rapidly scale, through decentralised replication.

Sustainable DeFi will make it feasible for social, environmental, economic and climate impacts of any type to be systematically programmed into any financial transaction, business process, or other human activity.

Sustainable DeFi applies to all economic sectors, industries, geographies and socio-economic contexts.

2 People's Money

Enabling people to earn, invest and spend their money in ways that improve the current and future states of the world, is a profound paradigm-shift.

The August 2020 *People's Money* report of the UN Task Force on Digital Finance for the Sustainable Development Goals [1] identifies that:

"Historic opportunity, combined with unprecedented crisis, provides a unique moment and imperative to act in harnessing digitisation to accelerate financing of the Sustainable Development Goals (SDGs)".

The report warns that *"Failure to act would be a wasted opportunity and risks finance diverging from the needs of citizens for inclusive sustainable development".*

People's Money makes specific calls to action, defines the moral imperative for building citizen-centric financial systems, demonstrates a broad political mandate, and identifies specific catalytic opportunities to immediately start making progress, by building sustainable digital financing ecosystems. *People's Money* is a framework for:

"Triggering broader systemic changes by driving innovation, disrupting stagnant markets, undermining rent-taking, increasing accountability, and encouraging governance innovations"

by:

1. Channelling domestic savings into development financing.
2. Enhancing financing for small and medium-sized businesses (SMEs).
3. Digitizing public financing and making public budgets and contracts transparent.
4. Embedding SDGs into the decisions made in financial and capital markets.
5. Shaping consumption decisions through improved information and choice architecture.

These catalytic opportunities:

"cover much of global finance, from the vast pools flowing through global financial and capital markets, to public finance that makes up a major part of the global economy, to the aggregated potential of citizens' savings and consumer spending, and the lifeblood financing for the employment and income-generating world of SMEs".

We believe Sustainable DeFi with impact verification is a fundamental technological breakthrough for people's money to finance a sustainable future.

Providing composable financial lego and accountability systems for building citizen-centric sustainable local economies.

3 Impact Tokens

Impact Tokens are the units of value which can be created through the Internet of Impact.

Each Impact Token represents a Verified Outcome State, in the form of a non-fungible token (NFT), which is backed by impact data assets and verification proofs, with embedded executable rights.

3.1 Verified Outcome States

An Outcome State is a representation of the cumulative claims about what has changed in the state of the world, at a point in time.

To deliver Sustainable DeFi solutions, we need to innovate how Outcome States are used to drive digital transactions and information-flows.

The ixo protocol defines an open standard and methods for tokenizing Outcome States, using Verifiable Claims which have been independently verified.

The legitimacy of an Outcome State is established by verifying that claims about this state are true and by demonstrating a positive correlation between prior state-changes, with the observed outcome state.

Factual truth and positive correlation are both probabilistic statements, which can be statistically predicated and cryptographically verified.

State representations are recorded as Verifiable Claims. Which must provide sufficient good-quality data as evidence, to be verified with cryptographic proofs and then represented as non-fungible tokens.

Impact Tokens have intrinsic value which is directly related to the value people place on outcome states relevant to their real-world contexts.

Impact Tokens could replace all tradable analogue instruments, such as

- *Verified Emission Reduction Certificates* for Carbon Credits,
- *Renewable Energy Certificates* for clean energy outcomes,
- *Qualification certificates* for educational outcomes,
- *Biodiversity certificates* for nature outcomes,
- *Immunisation certificates* for health outcomes.
- Or any other verified outcome states that people care about, are willing to invest in, work towards, or spend their money on.

Impact Tokens can be built into any financial transaction, capital allocation, government expenditure, business process, or consumer product. The economic space for Impact Tokens is therefore large.

Impact Tokens can be bought or sold, swapped, invested in, collateralised, or used in tradable financial derivatives, such as warrants, options and futures contracts.

We anticipate that Impact Tokens have the potential to become the tokenized commodities of sustainable finance markets.

3.2 Data Assets

Impact Tokens produced through the ixo protocol are data-rich. And can be further enriched by the insights and value added by Prediction Oracle services.

Impact Tokens, together with their linked data assets, may therefore also be seen as data commodities. Which can be sold, traded, rented, or licensed through new data marketplaces, such as Ocean Protocol.

The potential societal and commercial value that can be extracted from abundant, accessible, consented, high-quality Impact Data is extraordinary.

Especially considering that lack of data is the most-cited impediment to deploying capital for impact [4].

3.3 Accorded Rights

Depending on the class of Impact Tokens, this may accord rights to the token controllers/owners, including executable rights for invoking services – such as the right to mint derivative fungible tokens and sell fractional shares in the Impact Token.

4 Programmable Capital

The Internet of Impact is used to program capital and other resources into producing sustainable outcome states in the real world.

Alphabonds are the world's first cybernetic Sustainable DeFi mechanism which is built into the Internet of Impact. Alphabonds dynamically adjust the blockchain state in response to real-world risk signals.

Developers can use the Alphabond mechanism to build novel applications for a wide range of use-cases, such as:

- Impact Bonds that return outcome payments.
- Innovation Bonds that return a share of IP rights or future revenues.
- Insurance Bonds that make event-based payouts.
- Equity Bonds that convert to discounted share distributions.
- Collateralised Debt Bonds that return loan repayments with interest.
- Or any other conceivable Sustainable DeFi application that adapts to external state-change signals.

The ixo Bonds Module also provides a library of generic fixed parametric bonding curves that can be used for other applications, such as Community Currencies which are issued against a fractional reserve.

This class of Sustainable DeFi applications therefore has far-reaching potential to be used for implementing more sustainable solutions in finance and investment, insurance, equity and debt financing, commodity trading and supply chains.

A computer-aided design (cadCAD) tool enables Alphabond implementers to simulate, calibrate and test new classes of Alphabonds for novel use-cases.

4.1 Token Bonding Curves

DeFi protocols use token bonding curve mechanisms as automated market-makers and for continuous financing processes. However, these DeFi mechanisms have generally been static, with fixed *a-priori* assumptions about the interaction between the crypto-economic mechanism and external systems.

With most token bonding curve mechanisms to-date, changes in the state of external systems cannot modify the bonding curve configuration during live execution. This may result in pricing and supply anomalies, such as tokens being mis-allocated on both buy-side and sell-side, with losses in risk correlation.

DeFi systems implemented in the unpredictable real-world, or with complex economic mechanisms, have inter-dependencies that produce non-linear, compounding risk. Which can lead to the systemic collapse of non-adaptive financing mechanisms.

These constraints are addressed by Alphabonds.

4.2 Risk-adjusted Bonding

Alphabonds have been engineered to internalise and control investment risks, to make investing in outcomes safer, more efficient and scalable through replication [6].

The mechanism implements a novel class of parametric token bonding curves, which adapt the bonding curve algorithm in response to external state changes.

This enables dynamic, risk-adjusted pricing of shares in a bond's liquidity reserve and in the distributions of future returns. By algorithmically re-calibrating the current-state costs and risks of capital allocations, against the probability of success.

The mathematical proofs, engineering designs and simulations for validating this mechanism are detailed in a System Specification, developed in collaboration with BlockScience [5].

4.3 Alpha Risk Signal

Information about the observed state of the real-world is fed into the Alphabond as an Alpha Risk signal. *Alpha* predicts the probability (ranging from 0 to 100 percent) that an investment will succeed to deliver an expected future-state payout. For instance, Impact Bonds pay an Outcome Payment back to the bond investors when an outcome state target is reached.

As the value of Alpha changes over time, this adjusts the shape of the bonding curve through a coefficient that modifies the algorithmic price of the token, in relation to its current reserve. If the probability of success decreases, the bond retains a higher reserve ratio to protect investors.

Figure 1 demonstrates how Alpha inputs over time update prior probabilities, to adjust the bonding curve algorithm.

An Alpha signal could, in principle, be derived from any credible source of information which has predictive value — including AI oracles, IoT devices and prediction markets.

4.4 Internal prediction market

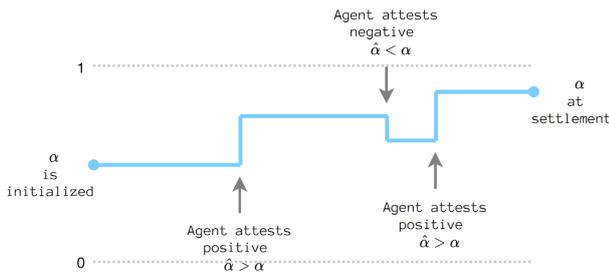When data is unavailable – for instance, in novel project implementations, the ixo blockchain SDK provides a
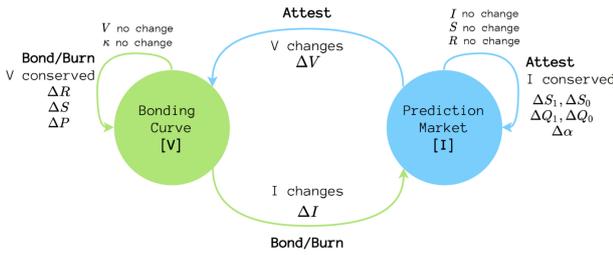
Figure 1: *Alpha Signal over time*

Figure 2: *The Composite Alphabond Mechanism*

Risk-prediction module for implementing an internal prediction market mechanism.

The risk-adjusted bonding and internal risk-prediction mechanisms are tightly coupled in the Alphabond system, as depicted in Figure 2.

The technical design of these composable mechanisms has been subject to extensive engineering research, mathematical validation and cadCAD simulation testing [6].

The ixo blockchain Risk-prediction module may also be used as an alternative, or supplement, to obtaining Alpha predictions from external Oracles.

The Internal Prediction Market mechanism offers bond token-holders the option of taking positions in Success or Failure pools, based on their private beliefs of the Risk Alpha.

The pay-out mechanism is designed to drive outcomes biased towards success.

But this also provides a fractional hedging mechanism, in case of failure.

An agent may attest both positively and negatively with subsequent actions, reflecting changes in their conviction about a project's chances of success.

Agents may choose to participate in only the bonding curve, or the bonding curve and internal prediction market.

Unallocated tokens minted through the bonding curve can be burned back to the curve to reclaim the collateral. But when tokens are attested towards the success or failure options pool, they cannot be unattested, withdrawn or re-cast.

4.5 Outcomes-based Financing

Alphabonds could overcome many of the operational impediments to issuing conventional bonded capital instruments, such as:

- The need to form all capital commitments upfront.
- Technical constraints to quantifying project risks *ex-ante*.
- Achieving investor consensus on the risk premium.
- Restricted participation options, due to fixed entry or exit points.

Risk-transfers to investors in traditional results-based financing mechanisms produce a bias towards funding lower-risk endeavors. Which diminishes project innovation and limits capital allocations to a subset of interventions that are implemented in carefully controlled contexts.

Traditional outcomes-based financing mechanisms will therefore not produce the scale and pace of changes in the state of the world that are needed to achieve the SDGs by 2030, or to significantly impact on the race against climate change and ecological degradation.

Alphabonds have the advantage that capital does not have to be formed in advance. Investors can choose to enter and exit at the bond price ranges that satisfy their risk-return preference – depending on how this has been configured.

Alphabonds allow for either a pre-specified or adaptive risk tolerance level to be incorporated into each bond instantiated, to fit the risk preferences of a representative class of investor.

In cases where an underlying investment fails to perform to the investor's expectations, they have the option to exit through the Alphabond – if there is sufficient liquidity, or by selling their bond share tokens through a secondary market.

The ixo blockchain SDK Bonds Module includes a Uniswap-style AMM for trading token-pairs.

4.6 Pricing Signals

Alphabonds provide real-time pricing signals which reflect both the performance of an underlying investment and investor sentiment.

Pricing signals can have a powerful influence on both investment and project implementation decisions. Providing an information-feedback loop that can direct the investment towards achieving successful outcomes, by adapting to the complex, dynamically changing state of real-world contexts.

4.7 Scaling through replication

By programmatically automating and decentralising the processes of forming, allocating and verifying the impacts of capital investments, Alphabonds locally control risks, so they can be scaled through replication.

As an example, the ixo Foundation is demonstrating with a leading traditional investment institution how a large, costly, "too big to fail" Impact Bond for primary education in India can be replaced by unitised portfolios of Alphabonds.

Each Alphabond instance limits the financial and operational risks to an autonomously controlled DeFi investment within a local context. Informing investors, implementers and other stakeholders with real-time data. Whilst benefiting from local governance, local knowledge, local ingenuity, local resources, and meaningful local stakeholder participation.

5 Prediction Oracles

ixo Prediction Oracles are a new class of blockchain services for the Internet of Impact.

Blockchain oracles commit information about the state of the world into blockchain smart contracts and stateful databases. Typically, blockchain oracles are un-opinioned and their purrpose is to securely communicate factual information into the relying mechanism, from trusted data sources. These signals can be programmed to change the blockchain-state in ways that are predictable and deterministic.

The ability to drive state-changes based on real-world observations goes well beyond the capabilities of established blockchain oracle systems.

In contrast, Prediction Oracle services are opinionated about claims which make assertions about the state of the world.

Service providers implementing Prediction Oracles use their domain-specific expertise and established rubrics to evaluate each claim and apply statistical methods, together with cryptographic verification, to infer the probability that each claim is both factually true and positively correlated with the claim subject.

Prediction Oracles produce verified data assets, in the form of W3C standard Verifiable Credentials. Which may be further enriched with reference data and information from other sources, adding the value of expert opinion and specialised computation.

5.1 P-functions

Prediction Oracle services can offer a wide range of data-driven Precision functions (P-Functions), giving investors and project implementers access to intelligent systems and human expertise for:

- Proofing claims.
- Personalising services.
- Planning.
- Prescribing interventions.
- Predicting Outcomes.
- Programming transactions.
- Preventing risks.
- Protecting against threats.

5.2 Data Science

Prediction Oracles open up the powerful intersection between AI/data-science and blockchain technologies. Continuously improving their performance by using data for machine learning and intelligent analytics. For example, in Alphabonds, this feedback loop is calibrated by the binary success or failure outcome state of each bond.

As volumes of verified claims data increase, this machine-readable, semantically standardised data can be shared and pooled across projects, for Prediction Oracle service-providers to gain system-wide insights, gather human intelligence, and use machine-learning, to optimise their prediction capabilities and to build new types of oracle services.

The need for Prediction Oracle training data-sets for federated learning should drive the creation of decentralised impact data marketplaces. Potentially providing additional revenue to investors and project owners.

Data assets are tokenized and traded through the Internet of Impact as NFTs, with executable data access and usage rights which are mediated through a delegatable access-control mechanism, using Authorization Capabilities (zCaps). These data tokens can be rented, sold or exchanged through decentralised peer-to-peer marketplaces.

5.3 Oracle marketplaces

Delivering both Legacy and AI Prediction Oracles through the Internet of Impact should make these services more widely accessible and affordable to impact project implementers and investors everywhere. Legacy services provided by evaluators, auditors and certification agencies can now be technology-enabled.

The Internet of Impact Hub provides a network through which Impact Relayers connect project implementers and investors with Prediction Oracle services.

Prediction Oracles are remunerated through the ixo claims processing mechanism, with service fees automatically processed, accounted for and distributed by a programmable ixo-Blockchain SDK Payments Module.

We anticipate the emergence of a competitive marketplace for trusted oracle service-providers, with expertise in their respective domains.

A share of oracle fees is distributed to the originating Impact Relayer and to the Impact Hub treasury, to maintain and grow the network.

he historical performance levels of Prediction Oracle services can be transparently assessed using transaction analytics.

Tooling, such as Jupyter Notebook integrations, will be made available for any data-driven service to build their own Prediction Oracles.

A Prediction Oracle Launchpad, implemented on the Internet of Impact Hub, will provide a funding and skills marketplace for researching, developing and distributing Prediction Oracle services.

6   The ixo Protocol

The ixo Protocol defines a new open standard for making verifiable claims about changes in the state of the world and to represent the resulting outcomes as non-fungible Impact Tokens.

This is a generic and versatile protocol that can be used to process claims relating to any real-world subject or observation. It enables any imaginable non-fungible resource – whether physical or conceptual, to be tokenized as a uniquely identified, verifiable, digital asset. Backed by high-definition data [7] and verification proofs, with embedded rights.

As an example of this versatility, the protocol could be used to evaluate and verify identity claims, to issue KYC Verifiable Credentials, which may be linked as resources to non-fungible, non-transferable, Membership Tokens.

We believe this protocol is the fundamental enabler of Sustainable DeFi, which must be embed financial mechanisms in stateful graphs of information, with verifiable evidence of real world state-changes and outcome states.

As Outcome States typically result from interdependent processes in the complex real-world, so claims about the observable changes in the state of the world must be linked across chains of causality.

Which requires claims to be connected through linked-data graphs, with edges that describe the relationships between identified organizations, agents, investments, verification mechanisms, data sources and indicator frameworks.

6.1   Inter-operable Open Standards

The ixo Protocol builds on core new decentralised, semantic web standards from the W3C, for Linked-data (JSON-LD), Decentralised Identifiers (DIDs), and Verifiable Credentials (VCs), which further extends into a family of related specifications – including Authorization Capabilities (zCaps) which provide decentralised, delegatable control over the processes and services for issuing and verifying claims, minting Impact Tokens and executing the rights accorded to token-holders.

To mint Impact Tokens, the ixo protocol implements the Interchain Identifier (IID) specification for next-generation NFTs and Verifiable Metadata.

ixo has been a leading contributor to the development and adoption of these various standards, since 2015.

These inter-operable standards make available to application developers all the tooling and integrations which have been built for DIDs – such as wallets, confidential data stores, and credential exchange mechanisms.

The ixo protocol directly addresses the challenge that legacy financial and impact measurement and management methodologies were never yet designed to be interoperable and are difficult to standardise.

6.2   Protocol Life-cycle

The ixo protocol defines the steps and methods for making and verifying Impact Claims and then tokenizing Verified Outcome States, as illustrated conceptually in Figure 3.

1. Observations about the state of the world are identified, using decentralised identifiers (DIDs) for the subject and classified for semantic context, using linked-data schemas.
2. Verifiable Claims are issued and cryptographically signed by identified, authenticated agents. This is typically done using client applications, such as mobile apps, to capture the claim data at the implementation edge of the real-world processes which are creating and observing change.
3. These claims, together with their evidence, are evaluated by independent Verification Agents, using standardised rubrics and statistical methods to form opinions whether each claim can be approved, to issue Verification Proofs.
4. Collections of verifiable claims over time, together with their verification proofs and additional information – such as the verifiable credentials of a project implementer, are combined to issue a Verifiable Credential for an Outcome State. Which includes a graph of the claims, proofs and credentials.
5. Impact Tokens are minted with this graph of data assets as Linked Resources, which can be retrieved by authorised users from a specified service endpoint – such as ixo Cellnode confidential data stores, in a permissioned way, using Authorization Capabilities (zCaps).

The configurability of this protocol, together with the flexibility of decentralised, delegatable Authorization Capabilities (zCaps), enables complex business rules and workflows to be implemented through the Internet of Impact, in fully decentralized, controlled and secure ways.

7   ixo Blockchain SDK

The ixo blockchain SDK offers modular components for configuring and deploying sovereign network zones of the Internet of Impact.

Engineered using the Tendermint consensus engine, Cosmos SDK framework, Inter-blockchain Communication, and related tooling [8].

This benefits from the diversity of novel innovations and technology advancements which are being made within this vibrant ecosystem of researchers, engineers, entrepreneurs and users.

7.1   Modular architecture

In addition to core Cosmos SDK modules, such as Staking and Governance, the ixo SDK includes mod-
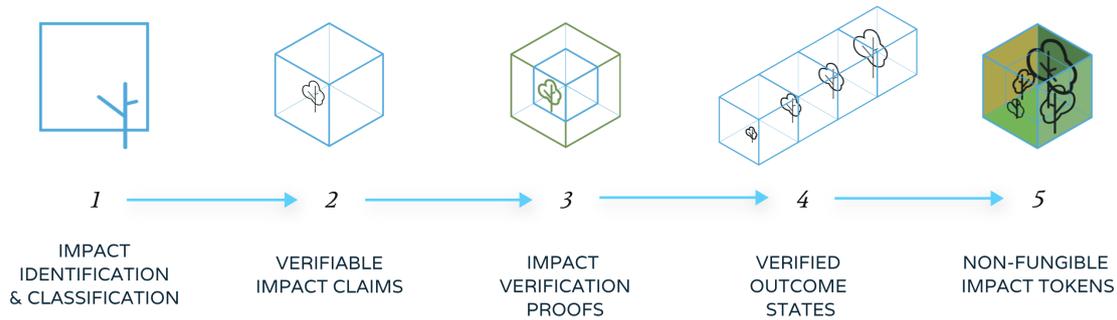
1 — IMPACT IDENTIFICATION & CLASSIFICATION

2 — VERIFIABLE IMPACT CLAIMS

3 — IMPACT VERIFICATION PROOFS

4 — VERIFIED OUTCOME STATES

5 — NON-FUNGIBLE IMPACT TOKENS

Figure 3: *The ixo Protocol Life-cycle*

ules which have been purpose-built to implement the ixo Protocol. Including: Decentralised Identity, Alphabonds, Risk-prediction, Payments, Claims Processing and Interchain Standard NFTs. This SDK can be extended by developers adding or modifying modules, with almost limitless configuration possibilities.

7.2 The Impact Graph

At the data layer, ixo protocol blockchains hold system-level state in the directed acyclic and linked-data graphs which together form *The Impact Graph*.

The Impact Graph records metadata about the state of the world in stateful, ordered, navigable, privacy-preserving, distributed registries of agents, claims, organisations, projects, oracles, investments and outcome states.

The data architecture of this graph increases the resolution of information about impact, by encoding each data object as a node, with a decentralised identifier. The relationships – edges, between nodes are encoded with linked-data contexts, which increases the dimensionality of the data.

This allows changes in the state of the world to be compared over time and attributed to causal chains, with linked evidence.

By design, humans are included in this graph as addressable and authenticated entities – using self-sovereign identifiers. Which puts people in the loop as agents making transactions and interacting with the cyber-physical mechanisms of the blockchain – such as Alphabonds, to produce state transitions through their actions. This should enable new forms of citizen-centric sustainable finance, organisation, action and governance.

Linked-data allows us to establish a common global ontology, using semantic schemas. Which extends to the ontology of measures – such as standardised sustainable development indicator frameworks.

Which makes the rubric for impact measurement and reporting interoperable and comparable across previously silo'd systems.

Higher degrees of resolution, with stateful structured data, should enhance the quality of intelligence gathered and shared through Internet of Impact networks.

The graph also serves as a configuration space for encoding future system-level target states for outcomes-based financing. For instance Alphabond Sustainable DeFi applications can incentivise stakeholders towards achieving desired future state outcomes, such as net-zero targets for carbon emission reductions [9].

Over time, the Impact Graph will grow our collective intelligence to empower more precise service matching, resource allocation, data-sharing digital asset exchanges.

7.3 The power of graphs

Considering how graphs have powered the growth of the Web 2.0 Internet giants, such as Google's Knowledge Graph, Facebook's Social Graph and Amazon's Trust Graph, we see the opportunity for the decentralised Impact Graph to power the creation and rapid growth of new digital marketplaces for products and services directed toward financing, delivering and verifying sustainable impact.

8 Internet of Impact Networks

The Internet of Impact infrastructure is delivered through networks of Level-1 Cosmos blockchain nodes

implementing the ixo protocol, and interconnected by IBC Relayers through the Inter-Blockchain Communication Protocol (IBC), with a Hub and Zones topology.

These networks are anti-fragile and can be made incorruptible, when fully decentralised, with governance and economics distributed amongst all stakeholders. This is particularly important for producing and reporting impacts in contexts where there are strong political, social or commercial forces at play which are resistant to changing the state of the world.

8.1 The Internet of Impact Hub

The Internet of Impact Hub provides the first global network of provably carbon-neutral ixo Protocol blockchain nodes, which forms the backbone routing infrastructure for this Internet.

The Hub is globally distributed and will initially be operated by up to 150 leading organisations who serve as network validators and Impact Market Relayers.

The Hub inter-connects sovereign Internet of Impact Zone networks, through to the broader universe of blockchains, using the Inter-Blockchain Communication Protocol (IBC), with bridges into Ethereum and other networks.

Applications from other Cosmos blockchains, or even other ecosystems, such as oracles from Chainlink, carbon registries from the Regen Network, data marketplaces from Ocean Protocol, or decentralised machine learning from Fetch.ai, will become available to users of the Internet of Impact.

User from other networks can also use the services of the Internet of Impact, which potentially brings the ecosystem of sustainability focused products, services and markets into any blockchain application on any network.

8.2 Impact Market Relayers

Nodes of the Hub are hosted by a network of Impact Market Relayers, who are well-recognised sustainability and impact-focused market-making organisations across all geographic regions. Representing a wide range of market sectors and stakeholders.

Impact Market Relayers provide both online and physical channels into their regional or sector-specific marketplaces. Market Relayers may also offer marketing and technical support, to connect Internet of Impact users to agents, applications, services, data, financial capital and digital asset exchange venues.

This should enable all market participants to operate, transact and invest more effectively in the Impact Economy and to create new markets for impact.

8.3 Internet of Impact Zones

Impact Zones are autonomous networks ixo protocol blockchains, which may be deployed locally or globally,

configured with application-specific security, privacy, governance and economic models.

The first Impact Zone is the Hong Kong Impact Data Consortium, which is providing a platform for growing, financing and strengthening the social sector, through a consortium funded by the Hong Kong government Social Innovation and Entrepreneurship Fund.

8.4 Carbon-neutral networks

A token slashing mechanism for offsetting the carbon costs of Internet of Impact networks will be built into the Proof-of-Stake security mechanism of the ixo protocol blockchain.

Network Validators who operate nodes will be required to make claims about their carbon emissions, which will be independently verified.

Nodes which don't use renewable energy sources, or do not voluntarily offset their carbon emissions, will be penalised by having a proportion of their staking deposits periodically slashed, to be automatically traded for Carbon Impact Tokens that offset the emissions.

The Internet of Impact Hub will implement this mechanism with real-time transparent and verifiable monitoring of the network's carbon balance.

9 The Internet of Impact Applications Stack

The open-source Internet of Impact applications stack includes mobile, web and IoT client interfaces for performing claims submissions, evaluations, issuing Verifiable Credentials and financing outcome states. Claims data is processed and stored in stateful, decentralised confidential data stores. Prediction Oracles provide their services through standard APIs, with tooling such as Jupyter Notebooks and software integrations to third-party information sources.

Reference software applications developed by the ixo open-source community demonstrate what can be built on the open architecture and standards offered by the Internet of Impact.

Developers are free to reconfigure or build on these open-source implementations, or to innovate entirely new software solutions and integrations.

10 The IXO Token

IXO is the first staking token of the Internet of Impact. This enables token-holders to self-stake or lease their IXO Tokens through a delegation mechanism for Proof-of-Stake Bonding. Which gives stakeholders the right to perform work and receive shares of fee distributions for their contributions, from Impact Market Relayers.

IXO tokens staked in service contracts give users access to message processing (gas), claim submissions,

oracle services, data hosting, submission of governance proposals, listing projects, digital asset and credential issuance, identity verification, membership registration, subscriptions, dispute-resolution, rental of digital assets, or any other services which are built on the Internet of Impact and utilise the Hub.

Token-holders may choose to stake IXO as collateral, to provide liquidity for loan mechanisms, supply tokens into Automated Market-Maker Liquidity Reserves, provide performance guarantees, curate registries, or participate in Alphabond Risk-prediction pools.

Holding minimum stakes of IXO Tokens, together with digital membership credentials, may offer Stakeholders additional benefits, such as value-added services and discounts offered by Impact Market Relayers, Impact Zone networks and – in future, other non-ixo networks.

Governance staking gives Stakeholders the right to submit and vote on various types of proposals. Depending on the type of voting procedure implemented, the quantity of IXO tokens held by a Stakeholder may be used in weighting the results. Governance Bond applications – using the ixo Alphabond DeFi mechanism, may pay out yields in IXO tokens.

11 Tokenized Impact Economy

We envisage a future in which Impact Tokens will represent the state of the world for all the outcomes that people or organisations care about and value.

Tokenizing the non-fungible social, environmental and economic outcomes — such as carbon emission reductions, children's education, or population immunisation, will add new and renewable forms of capital to the economy.

Tokenized outcome states can be paid for, sold and traded in both traditional capital markets, as well as the fast-growing digital asset marketplaces.

This provides a core building-block for innovating how we program capital for sustainable finance and impact investing , using Sustainable decentralised finance (DeFi) mechanisms such as Alphabonds.

It is conceivable that the Tokenized Impact Economy will become the mainstream economy. As capital markets shift towards financing sustainable outcomes and are compelled to demonstrate the impacts of capital allocations. Impacts will have to be explicitly identified, proven and valued in social, environmental and economic terms.

Tokenization of impact is directly relevant to how the world will finance and track progress towards achievement of the Sustainable Development Goals and climate impact mitigation over this decade, to 2030.

12 Digital Immune System

The Internet of Impact design is based on the biomimetic principles of natural immune systems.

It enables decentralised, autonomous localised sensing of social, environmental, economic and climate threats or opportunities.

With response mechanisms for coordinating, targeting and amplifying both localised and systemic actions.

In the process this builds innate intelligence, latent memory and preparedness, to speed up and replicate future responses.

Using tokens like antibodies to carry information and potentiate, aggregate, neutralise, or catalyse changes in the state of the world.

This is the Digital Immune System for Humanity.

13 Conclusion

The Internet of Impact is a much-needed global public good. It provides an open, standards-based digital infrastructure that is built on the latest open-source, inclusive blockchain and sovereign data technologies. Which are easy to customise, evolve and deploy at Internet scale.

Financial and data applications built on the Internet of Impact could profoundly transform how the world finances, implements, measures, values, and creates markets for impact.

Offering an unprecedented opportunity to imagine and create a citizen-centric new world economy. Which can generate prosperity now, by giving people the information and tools to earn, spend and invest their money in ways that will lead to a more sustainable future.

References

[1] UN Task Force on Digital Finance for the SDGs. *People's Money: Harnessing Digitalization to Finance a Sustainable Future*. August 2020.

[2] Clark A. Mihailov A. Zargham M. *Complex Systems Modeling of Community Inclusion Currencies*. Economics Discussion Papers. Department of Economics, Reading University, 2021.

[3] Mqamelo R. *Community Currencies as Crisis Response: Results from a Randomized Control Trial in Kenya*. Minerva, March 2021.

[4] Financial Centers for Sustainability. *Shifting Gears II*. FC4S, January 2021.

[5] Conway S.B. *Risk-adjusted Token Bonding Curves*. Medium, June 2019.

[6] BlockScience. *Risk-adjusted Bonding Curves: Systems Specification*, Github, 2020.

[7] Conway S.B. *High-definition Data*. Hacker-noon, December 2018.

[8] Kwon J, Buchman E. *Cosmos White Paper*. A living document.

[9] Zargham M, Shorish J, Paruch K. *From Curved Bonding to Configuration Spaces*. IEEE International Conference on Blockchain and Cryptocurrency (ICBC), 2020