Finance 4.0—A Socio-Ecological Finance System

Mark C. Ballandies, Marcus M. Dapp, Benjamin Aaron Degenhart,
Dirk Helbing, Stefan Klauser, and Anabele-Linda Pardi

Abstract *This contribution develops the framework of a novel, socio-ecological finance system that enables the incentivization of environmentally friendly behavior, socially responsible production, resource recycling, sharing and more. We call this system Finance 4.0—where Finance 1.0 refers to a physical coin-based system, Finance 2.0 to a fiat currency system, Finance 3.0 to blockchain finance, while Finance 4.0 stands for a multi-dimensional, real-time feedback system that combines blockchain technology with the Internet of Things. Instead of “Finance 4.0,” we will also often use the abbreviation “FIN4.”*

In comparison with citizen scores such as the Chinese social credit score, the FIN4 approach is different in a variety of aspects:

- *FIN4 is not aimed at punishment and control, but rather at helping to encourage, empower and coordinate sustainable and other favorable action.*
- *It is being built for local, temporary measurements and feedback, not for global surveillance and control.*
- *It seeks to protect the privacy of people rather than to keep information about everyone and every action forever.*
- *It is not focused on the individual in the sense of profiling and targeting, but on favorable interactions and our social and environmental goals.*
- *It offers a multi-dimensional choice of options instead of trying to determine every individual’s action through behavioral manipulation and control.*
- *It has a participatory opt-in nature, where people can co-create the incentive system in such a way that they can reach their goals more successfully.*

A previous version of this chapter has been published as a technical report entitled “FuturICT 2.0: Towards a sustainable digital society with a socio-ecological finance system (Finance 4.0)”, accessible here: <http://ebook.finfour.net>.

M. C. Ballandies · M. M. Dapp (✉) · B. A. Degenhart · D. Helbing · S. Klauser · A.-L. Pardi
Computational Social Science, Stampfenbachstrasse 48, 8092 Zurich, Switzerland
e-mail: mdapp@ethz.ch

© The Author(s) 2021

M. M. Dapp et al. (eds.), *Finance 4.0—Towards a Socio-Ecological Finance System*,
SpringerBriefs in Applied Sciences and Technology,
https://doi.org/10.1007/978-3-030-71400-0_4

- *With multi-dimensional incentivization, it becomes possible to advance several goals simultaneously; thereby, many more people can benefit from the interactions they engage in, as multi-dimensional value exchange increases the solution space enormously.*

Keywords Blockchain · Sustainability · Decentralized governance · Incentive system · Value-sensitive design · Cryptoeconomics

The Finance 4.0 Ambition

The world is facing existential threats. These challenges are putting pressure on our economy, society and environment. The unresolved problems of the 2008 financial crisis still endanger the economic stability of Europe and the world. Currently, many nation states struggle to control the power of major banks and global corporations. We are told to accept they are “too big to fail”—thereby skewing incentives and creating moral hazards.

Digitization and globalization are increasingly creating an interconnected world. While this process has brought much progress and improved the standard of living, it has also produced new threats, in particular a crisis in terms of sustainability.

The globalized economy now comprises a massive, complex network of systems that is much harder to map and control than the economies of the twentieth century. One of the critical problems is that today’s economic order is creating systemic market failures due to all sorts of unwanted externalities. A concerted global effort to regulate and account for these externalities is yet to be seen. Pricing externalities in dollars, for example, is not expected to be sufficient. As a result, a series of ecological and economic crises threaten the very basis upon which our economy and society are built (Fig. 1).

What is more, access to scarce resources is becoming a growing concern. The use of fossil fuels and raw materials has tripled in the last 40 years [1], and climate change may lead to the extinction of one sixth of all species [2]. Not to mention the additional challenges posed by war, terrorism and the migration of displaced people. At every scale, individual incentives today are often misaligned with the core values of our societies. As a consequence, the world suffers from an overall lack of sustainability. How should we tackle this web of interdependent, complex crises and mitigate some of the fundamental challenges humanity faces? This is where FuturICT 2.0 comes in. The project pursued disruptive innovation to address the root cause of these problems—a lack of sustainability—by combining the Internet of Things, blockchain technology and complexity science to open up new opportunities.

In alignment with the UN Sustainable Development Goals (and future iterations thereof), our proposal called “Finance 4.0” concerns a multi-dimensional incentive system to manage complex systems and promote a circular and sharing economy. The aim is to create a high quality of life for more people with fewer resources by aligning

Fig. 1 Ecological footprints of selected countries (National Footprint Assessments 2017, Global Footprint Network)

individual incentives with core values—defined and driven by the communities themselves.

Finance 4.0 (short FIN4) encompasses a socio-ecological finance system, a novel economic system and a new social contract. With respect to finance, we propose a multi-dimensional cryptocurrency ecosystem promoting decentralization and positive action. Regarding the economy, we suggest a new, privacy-preserving incentivization scheme influencing production and consumption in a way that will promote a circular and sharing economy. This new system should be held together by a new kind of social contract fostering community-based decision-making, allowing for subsidiarity as well as local and personal diversity.

FIN4 is democratic, pluralistic and inclusive. It leverages information and communication systems to empower everyone to take better decisions, be more creative, and coordinate or cooperate with others—thereby leading to better business models, products and services, smarter cities and smarter societies.

FIN4 is ambitious. Globally, we face what we could describe as a misalignment of goals and incentive structures. There are some common goals with respect to sustainability: the United Nations Sustainable Development Goals (SDGs) [3] and the Paris Agreement [4]. However, while agreeing on a joint set of supranational goals is certainly important, it marks only the first step in a long and challenging transition.

How to translate global goals into individual incentives and collective actions? The first pillar builds on the concept of nation states, which internalize the global targets by integrating them into their national legislation. This regulation-based approach is undoubtedly the most commonly considered when discussing the need for more sustainability, but it seems to be too slow.

The second pillar builds on mostly voluntary, often profit-driven contributions or on self-restraint of global corporations. However, this proves inefficient so far. By now, it is clear that these pillars alone are insufficient to make our world more sustainable quickly enough.¹

We therefore propose a third pillar, based on “co-opetition”: individual contributions that are coordinated and assisted digitally, which is the basis of the FIN4 system and the Climate City Cup.²

In order to develop this concept, accompanied by basic research in the respective fields, FuturICT 2.0 has proposed to develop a FIN4 demonstrator. This demonstrator should show that, with modern technology, it is feasible to create an environment that fosters sustainability without compromising human rights and subsidiarity. Its goal is to illustrate the possibility of an innovative framework with features such as the following:

- the ability to create bottom-up money similar to Bitcoin,
- multi-dimensional money exchange with multiple currencies representing various environmental, social and other kinds of values and costs,
- the use of this system to price and trade externalities of different kinds,
- suitable incentive mechanisms enabling a favorable (self-)organization of socio-economic systems on different scales,
- feedbacks promoting a circular and sharing economy,
- the possibility of taxation.

To achieve these goals, we wanted to combine the following technologies and principles:

- decentralized currencies and blockchain technology to enable reliable peer-to-peer contracts, allowing the creation of a direct and sustainable sharing economy,
- sensors and the Internet of Things (IoT) to make it possible to measure externalities and build a circular economy, with various externalities represented by different currencies complementing the current monetary system,
- specific community-based incentives to support the self-organization of complex systems and help them evolve towards a circular economy; more efficient use of resources by promoting social cooperation and climate protection,
- research could be conducted in many areas. Among other fields, the team has explored Distributed Ledger Technology (DLT) systems, behavioral economics, cryptoeconomic design, requirements design, proof mechanisms, identity and governance (see the Glossary for an explanation of special terms).

¹cf. <https://climateactiontracker.org/countries/>.

²cf. <https://climatecitycup.org>.

The Finance 4.0 Framework

One of the reasons for unsustainable behavior is the long period of time between our actions and the consequences they may have. For instance, people have been burning coal for two centuries and driving motor vehicles for one century, while carbon dioxide emissions have only recently been considered to be a serious global problem. Such circumstances create cognitive dissonance, i.e., an uncomfortable feeling of inconsistency.

FIN4 aims to create a self-organizing, highly nuanced incentive system that supports the daily decision-making of people by encouraging desirable actions and discouraging undesirable behaviors.

To promote sustainability, it is important that the FIN4 system takes externalities into account. However, the FIN4 system does this by *multiple* currencies, reflecting different societal values. By giving externalities prices and allowing them to be traded, they can be internalized to reflect costs and benefits more accurately in a multi-dimensional way. Externalities can be positive (like certain kinds of innovation or infrastructure) or negative (such as pollution).

FIN4 focuses primarily on positive action, rather than on sanctions, for the following reasons:

As an opt-in system, it would be almost impossible to motivate participants to join if they would face a negative balance of tokens, taking into account negative externalities. Obtaining tokens for positive action is a much better value proposition. FIN4, therefore, focuses on rewards for positive actions, rather than on punishments for negative actions.

Our daily choices often seem to be detached from our values. Using a smart distributed incentive system, however, communities can reward what they value—by issuing new types of tokens to address local needs.

These positive actions can be whatever the community considers to be valuable. Examples may include planting trees, using a bike rather than a car, helping a person in need or recycling.

In this case, the tokens can take on any form of value for the communities. They can be fully symbolic (imagine a virtual trophy representing a tree you have planted), give access to a service (such as free bicycle maintenance) or even have a monetary value.

The core process of FIN4 is illustrated in Fig. 2.

A new type of token is created with a name, a short ticker symbol (similar to “USD” or “BTC”) and a statement describing the purpose of the token. Users can record actions and then claim the respective tokens. A claim may be verified in three different ways, which can be combined with each other:

- *sensor proofs* use data transmitted from an IoT sensor or device for location, humidity or temperature, for example. This includes mobile proofs from a user’s smartphone (such as photographic documentation).
- *social proofs* mean other users attest that a certain action has been performed.

Fig. 2 Rewarding positive actions is the core of Finance 4.0

- *third-party data proofs* utilize external sources of data, where this cannot be generated within the FIN4 system directly (Fig. 3).

Let us here discuss the example of litter disposal.

Alice creates a type of token for incentivizing people to pick up and dispose of litter they find in public parks. The community collectively likes this idea and adopts it. While hiking, Bob finds an empty plastic bottle and takes a couple of photos showing where he found it and where he disposed of it. Bob uploads these pictures to the claiming platform and other users approve his claim, rewarding him with a number of positive action tokens.

Sensor or mobile proofs require security measures in the hardware or software to prevent cheating, such as double claiming. Social proofs need an additional incentive

Fig. 3 Communities create tokens to represent positive actions. Users prove to the system that they performed such actions to receive the respective tokens

layer that motivates other users to provide attestations in good faith, while also preventing collusion.

Placing real-life data on the blockchain is a non-trivial problem and can be susceptible to manipulation or mistakes. In practice, it will likely require combinations of these proofs (like in our example above) in order to adequately prevent cheating. After all, data may not necessarily represent the truth of real-world actions. An oracle based on third-party data might be required to prove that submitted data is correct, before it is irrevocably placed on an immutable blockchain. Once a claim has been proven using these approaches—or indeed combinations of them—the tokens are minted and transferred to the claiming user.

The prover may be the token's creator, a dedicated group of people (such as token holders) or any random user, depending on the nature of the action and type of token. The most effective and useful token systems will likely be approved and adopted by the community in a self-organized and self-sustaining manner.

We envision a multi-layered, multi-dimensional system of decentralized digital cryptocurrencies created at different levels with different characteristics, serving different purposes.

The token systems may operate at a supranational, regional or local level. The different purposes may address environmental, social or other values relevant for sustainability or society.

The FIN4 core system comprises a token economy and a governance framework. The token economy gradually emerges as communities asynchronously create, obtain and trade positive action tokens, thereby creating a market for these positive actions.

In order to align user incentives towards the creation of this market, a governance layer is needed that supports the development of a healthy token economy. This governance layer uses a governance token (GOV) to offer mechanisms that allow users to collectively decide on which tokens to promote as “official FIN4 tokens” (Fig. 4).

Any system that allows users to propose new token designs will have to deal with the problem of spam. So, how can we ensure our ecosystem promotes useful token concepts? Rather than establishing rules and barriers to restrict the creation of tokens, our design leverages the innovative capacity of independent token proposals. Every token idea is welcome, but acceptance as an official FIN4 token requires users to vote for it with their governance (GOV) tokens. Thus, all users co-maintain a list of approved positive action tokens.

The *reputation* tokens (REP) to facilitate social proofs do not yet exist in our system. Their purpose is to help users establish trust in one another in order to interact effectively on the platform. Reputation should reflect the support of the system by the user (e.g., proving, voting, etc.) and not their actual positive action token holdings, which could otherwise introduce bias to the reputation system.

In our current design, users obtain reputation tokens by performing actions that support and strengthen the entire FIN4 system. As a minimum, the actions suitable for obtaining these reputation tokens include (1) the active gathering of tokens (low

Fig. 4 Human coordination in FIN4’s multi-token economy happens on two levels

reward), (2) participation in proof mechanisms (medium reward) and (3) the acceptance of token designs by curators (high reward). Finally, users should also be able to lose these reputation tokens.

Also, how can we incentivize entire communities that may already have their own tokens established to join the larger ecosystem? The idea is to represent the additional *liquidity* won when joining the larger FIN4 network through a “reserve currency” we call liquidity token (LIQ). This token would stand for the network effects gained when enabling larger networks and markets.

One conceivable, yet too simplistic approach would be to create the same number of FIN4 tokens for each accepted token proposal. The overall number of liquidity tokens would, therefore, be commensurate with the total number of FIN4 tokens in the system, thereby giving users more trust in using the different tokens and some assurance that tokens can be exchanged with one another. This could be based on the original idea of “Bancor” by John Maynard Keynes; however, the final design has not yet been decided.

Due to the nature of blockchain technology, blockchain creators are unable to prevent trades beyond the confines of the system. Our approach is to create strong incentives to use the platform, while preserving the freedom of users to leave at any time and take their token balances with them.

Furthermore, a form of *identity* is needed when users wish to participate in the governance of FIN4. Identity (ID) here corresponds less to the idea of a scanned passport and more to a concept of self-sovereignty built entirely within the FIN4 system or transferred from other platforms. For example, reputation mechanisms may establish identity over time.

Distributed Ledger Technology (DLT)

What definitions are currently used in practice for concepts like tokens, transactions and consensus? And what exactly is distributed ledger technology (DLT)?

The blockchain community still suffers from a general lack of a shared understanding of terminology, making comparisons between different blockchain-based projects difficult. To support a common understanding (and as part of our research towards the FIN4 system), we developed a systematic taxonomy of distributed ledger systems [5].

Accordingly, we define distributed ledger technology (DLT) as a range of distributed data structures in which entries are recorded by participants after reaching consensus on their validity. A consensus mechanism—the set of rules for transaction validation—is integrated into a DLT system to ensure system reliability, where no trusted third parties are required to authorize or validate entries. Distributed ledgers often support secure token economies. These rely on digital tokens and cryptographic techniques to determine how to perform exchange between participants. The most well-known and successful example of a DLT system is Bitcoin.

While the taxonomy paper mentioned above provides a more extensive introduction to the topic, a conceptual architecture of distributed ledger technology is shown in the figure below.

Incentivization may occur on either the consensus or action layer. The first generation of blockchains are known as cryptocurrencies. They are chiefly based on incentive systems that maintain consensus mechanisms in the digital world.

The second generation of blockchain projects are based on smart contract engines allowing for the creation of tokens. These tokens can be utilized to incentivize people or machines to perform certain actions in the real world. One example for a token standard that creates fungible (exchangeable) tokens is the widely used ERC20 token standard on the Ethereum smart contract platform³—also used as a basis for our positive action tokens in the FIN4 system.

FIN4 takes full advantage of this possibility by not only creating a range of platform tokens used for governance, but also by offering users mechanisms to create tokens as they wish (Fig. 5).

The taxonomy paper categorizes different examples of existing tokens by means of several attributes [5]. These attributes include the underlying source of value of the token, the regulation of action/read permissions, the supply policy, the transferability and the condition governing the minting of new tokens. It also covers the various consensus mechanisms that exist, such as “proof of work” or “proof of stake.”

The FIN4 system will foster communities that can create and use tokens to promote the sustainable action they consider important, following a consensus framework we like to call “*proof of good work*.”

Many aspects of cryptoeconomic design will be available to these communities when creating token proposals. Community members will be able to configure a

³cf. www.ethereum.org.

Fig. 5 Conceptual architecture of distributed ledger systems, based on [5]

range of token attributes. For example, what is the claiming process? Who is able to approve claims? And how many tokens should be minted for every verified positive action?

Value-Sensitive Design

The world faces major challenges as a consequence of insufficient sustainability. We assume that current economic incentives, which fail to effectively reward sustainable behavior, are partly responsible for this problem.

Sustainability

One of the key objectives of the FIN4 platform is to address sustainability issues and reduce negative environmental externalities with positive action. We hope to achieve this by creating a system that enables communities to define sustainable and socially desirable actions and to reward individuals who align their behavior with these goals, using exchangeable incentive tokens. Note, however, that not everyone needs to engage in the same kinds of actions to be rewarded. On the contrary: the system supports specific actions fitting personal preferences and talents. In this regard, the multi-dimensionality of the approach is highly relevant.

Inclusion

In order to achieve this transformation towards a world, which is more aware of sustainability, the FIN4 system follows a bottom-up approach that enables everyone to participate, contribute their own ideas and protect the system for the benefit of the community.

Communities should not only be able to determine the values and token concepts most important to them, but also to shape how the platform develops. The users themselves will also be essential for maintaining the system and for protecting it from abuse via the reputation tokens. These tokens will enable every user to have a say on which token proposals to accept. However, the weight that their votes carry will depend on how trustworthy their conduct has been so far.

Freedom

We believe that people should be encouraged, not compelled, to participate, which speaks for an opt-in platform. Users would be able to interact with the FIN4 platform as long as they wish—and also leave, whenever they want, perhaps even with the possibility to take their token holdings with them.

The decentral nature of permissionless DLT—for both data storage and decision-making—is intended to prevent a single point of failure or authority. This provides protection against censorship, inappropriate control, or other arbitrary interventions, since data is stored immutably on the blockchain.

User identities are pseudonymous, thereby protecting the privacy of individuals. Anonymity is an essential requirement of democratic systems with privacy protection. It allows participants to engage in independent decision-making.

The pursuit of multiple objectives can, however, result in conflicting goals, which we have realized in a dedicated ethics workshop with ethix.⁴ We attempt to minimize such conflicts using appropriate coordination mechanisms and, where they are too limited, suitable governance. We outline these ethical considerations below.

Preventing Misuse

We do not dictate what behavior we consider socially desirable. Instead, we leave this decision to the community. So, how to prevent misuse of the platform? If users acted in bad faith or for their own purely selfish interests, they may indeed start to reward actions with tokens that do not accord with the moral principles of the project. Such misuse would not only harm the FIN4 community, it might also have wider consequences for society.

⁴ cf. www.ethix.ch.

Nonetheless, we trust that a critical mass of users can prevent such misuse, as they have the power to vote down token proposals created in bad faith. Trustworthy users—i.e., those with more reputation tokens—will have a greater voice in determining the list of official tokens. This mechanism can also avoid excessive spam in the system.

Ensuring Democratic Legitimacy

The inclusive and voluntary nature of the platform means that the issuance of tokens will be legitimized by a high level of participation, with decision-making being subject to voting.

However, there is a risk that a consistent majority will end up holding a position of power, such that individuals with minority positions may be discriminated against to some degree. This could be exacerbated—to some extent—by reputation tokens, as they would allow trusted groups to accumulate voting power.

In order to prevent a scenario in which a majority suppresses minorities from happening, a maximum number of reputation tokens should be defined—with no user being able to hold more than this limit. This would help to contain the risk that a certain group accumulates too much power (see also the subsection below on “Governance”).

Avoiding Social Pressure

While we hope that FIN4 proves useful in promoting a sustainable society and that the platform enjoys widespread adoption, we realize that mass adoption could result in growing social pressure on non-users to join the platform. This would question the voluntary nature of the platform.

Those who choose not to participate may face exclusion from certain kinds of transactions—a situation that might put the core value of freedom at risk and would have to be counteracted.

Governance

There are also important ethical considerations in terms of platform governance.

Once the platform is launched, the integrated governance mechanisms will largely determine the success of FIN4—especially as we will then cede the content and structure to the community, losing our ability to make subsequent changes.

Anticipating these potential risks ahead of time is key. Therefore, our approach to governance includes the following:

- **Blockchain:** This technology permits decentralized decision-making as well as transparent data storage. The security risk is distributed across the network and, thereby, minimized. Furthermore, pseudonymous participation as implied by a

public blockchain is compatible with the core values of inclusion, privacy and freedom.

- **Openness:** The platform is open to anyone who wishes to participate. This is intended to legitimize the new decision-making processes.
- **Community moderation:** A hierarchy will emerge between users with different balances of reputation tokens, which are given to those users who commit time and effort to the platform. These tokens will help protect the platform from malicious actors. The combination of inclusion and a time- and effort-based hierarchy may produce both meritocratic and democratic effects. What is more, the use of procedures like “quadratic voting” would reduce the risk of certain users accumulating too much voting power.

The Cryptoeconomic Design of Finance 4.0

Relevance of Cryptoeconomic Design

As mentioned earlier in the DLT taxonomy section, there is a lack of commonly agreed terms in this field. This is also true for the term “cryptoeconomics.” Vitalik Buterin—the founder of Ethereum—posited that cryptoeconomics is a discipline that combines cryptographic proofs of past events with economic incentives to encourage future events as part of a blockchain system [6].

The cryptographic components mainly encompass consensus algorithms, enabled by digital signatures and hash functions, and have more recently progressed to include zero-knowledge proofs, multi-party computation and homomorphic encryption [7]. The economic components involve principles of game theory, mechanism design and network economics. As explaining all these terms is out of scope of this book, we recommend interested readers to consult the references to get a better understanding of them. In a nutshell, the aim of applied cryptoeconomics is to design new economies based on cryptographic tokens and mechanisms in order to create incentive systems for users.

Web 2.0 applications (known as Apps) refer to platforms like Facebook, Google or Amazon. These are to be contrasted with the emerging Web 3.0—and Decentralized Applications (known as DApps)—which are relevant to FIN4. Decentralized Applications run on peer-to-peer networks, where no node typically enjoys privileges over other nodes. This is quite unlike Web 2.0 Apps controlled by a central provider. While both cases require functional and error-free code, this is not enough for the Web 3.0. That is because DApps encode economic incentives using smart contracts in order to incentivize certain actions. In the example of Bitcoin, miners are rewarded with newly mined Bitcoins for successfully mining a new block. These mechanisms are cryptographically protected and practically impossible to change. As a consequence, modifications to the software require the coordinated effort of all

nodes. If only a majority of nodes cooperate, rather than all, the network runs the risk of diverging in a “fork.”

Even if the code of DApps is flawless, the decentralized system may still fail due to the mechanisms built into the network, if they are based on inaccurate assumptions about individual or collective user behavior. This is particularly true if the system neglects to consider potential misuse, malicious action, or user mistakes. Effective cryptoeconomic design (CED), therefore, needs to take all this into account (Fig. 6).

Effective CED is important for several reasons. First of all, implementing the values of a developer community into individual incentives for a larger user base is rather difficult. Good cryptoeconomic design seeks to reduce the potential for incentive misalignment at the various levels of the system as illustrated in the following figure based on Zargham [8]. The framework is useful for analyzing CED systems by highlighting the interconnections: five distinct layers, with each layer requiring the layer beneath and enabling the layer above.

Second, effective CED is vital since the possibilities to implement subsequent changes or corrections to a live DApp are very limited. Smart contracts written on a blockchain can neither be stopped nor modified easily.

Third, CED needs to take into account the challenge of designing a complex system. Here, multiple variables and interrelationships come into play, which allow for suitable self-organization and emergence of behavioral patterns.

Fig. 6 Creating interconnected collaborative communities (based on [8])

Fourth, cryptoeconomic design must reflect the implicit objective of cryptoeconomic systems to translate the values of a community into specific incentives for individuals. For instance, the Bitcoin community values secure and non-censorable transactions above everything else. The system, therefore, promotes decentralized mining to run the transactions. On the other hand, minimizing energy consumption was not considered an important value in the Bitcoin community and no incentive—other than waste minimization/profit maximization for miners—was therefore established to pursue it. The heated debate whether Bitcoin wastes energy or pushes the price of renewables close to zero over time, resulting in a net positive effect, is still ongoing.

Designing Cryptoeconomic Systems

The problems addressed by cryptoeconomic systems are invariably complex, and, as it is a new field, standard processes for cryptoeconomic design have not yet been established. However, a multi-scale perspective can be adopted to comprehend complex economic and cryptoeconomic systems. Policymakers can seek to change the global system behavior either via enforced rules (which we find problematic) or incentives (which we find more agreeable). These policies affect the local behavior of agents and, in turn, influence global behavior. Nevertheless, designing a cryptoeconomic system that works as intended is a complex problem requiring the configuration of various system attributes such as the permissions in a system, the supply of a token and the type of distributed ledger utilized.

In order to simplify this configuration process, the following three-step methodology can be utilized:

First, the system designer has to map the goals of a cryptoeconomic system to specific requirements of that system. Second, based on these requirements, the designer can utilize Fig. 11 from Dobler et al. [9] to identify the right system layout. Third, once a layout is chosen, the DLT taxonomy mentioned earlier [5] can be used to configure the system layout with the appropriate attributes (Fig. 7).

The Finance 4.0 Token Economy

The FIN4 system is designed to store a variety of information. This includes which tokens have been created, who has claimed which tokens, who has submitted proofs for actions, and who owns which tokens. This balance and tracking information is required for positive action tokens as well as meta tokens for FIN4 governance.

As an open, community-based system, FIN4 allows multiple roles for writing information to the blockchain. Depending on the proof mechanism, for example, any user can approve action proofs by other users. Moreover, users are able to create and

Fig. 7 Impact of system requirements on system layout (based on [5])

obtain positive action tokens anonymously; this helps to make the platform openly accessible.

We have also decentralized the necessary mechanisms to the greatest extent possible, to avoid the need for an “always-online trusted third party.”

According to the decision tree proposed by Wüst and Gervais [10], a permissionless blockchain is recommended for such a setup (Fig. 8). FIN4 is built using smart contracts secured by the Ethereum network (a permissionless blockchain system).

Fig. 8 Decision process for permission types in a Blockchain-based system (based on [10])

Thus, mapping our system goals and values (see the section on “Value-Sensitive Design”) according to the design requirements proposed by Dobler et al. [9], the FIN4 system requirements can be summarized as follows:

- **Transparency:** FIN4 aims to increase the visibility of certain undervalued actions. Many positive things that people do every day go unnoticed as the current monetary system does not ascribe value to this behavior. Visibility is also required in order for markets to emerge for the various positive action tokens, with much of this data stored and tracked on the blockchain.
- **Automation:** FIN4 aims to ensure that all users are treated as equal peers in the system, the rules for creating and obtaining tokens as well as governance need to be codified in a neutral way, with smart contracts.
- **Incentivization:** FIN4 aims to create a multi-dimensional incentive system to encourage more sustainable behavior, rewarding good actions with incentives in the form of various cryptoeconomic tokens.

With these requirements, the FIN4 system layout has to consist of a distributed ledger, smart contracts and cryptoeconomic tokens.

Applying Zargham’s layered model (see Fig. 9 and cf. Fig. 6), FIN4 is based on an enabling economy, consisting of a distributed ledger (DL[T]) and smart contracts (SC), ensuring durable data and trusted computation, in a permissionless environment. Above this layer, a set of constraints in the form of local mechanisms

Fig. 9 Interconnected layers of Finance 4.0 as a cryptoeconomic system with tokens representing [official] positive action ([O]PAT), reputation (REP), or governance (GOV)

(for actions, proofs and token curation) as well as incentives (to create and obtain tokens and the associated actions) are defined. The different tokens—[official] Positive Action Tokens ([O]PAT), Reputation Tokens (REP), and Governance Tokens (GOV)—allow for complex interaction patterns. Exposing such interactions to the real-world, as defined by the community’s needs, should lead to local agent behavior that is conducive to the global goals for the FIN4 system.

FIN4 ultimately aims to enable a new type of economy that better values sustainable action—from the perspective of communities themselves to society at large. This value should not be created in isolation, but result in a flow of values within the network to balance the demand and supply of positive actions, leading to the optimal allocation of resources to achieve global goals of sustainable behavior at scale.

Simulating the Token Design Space

Agent-based modeling (ABM) has been used extensively in the past few years [11–13] as a powerful tool, also in the context of econophysics [14], and especially for market modeling [15, 16]. Moreover, ABM-based computer simulations proved to be useful in the study of socio-economic systems and more [17–19].

Generally, the agents in ABM simulations are given attributes to define their behavior. They can adapt according to situations and interact with each other [20]. In our agent-based approach, we have human agents which fulfill certain roles (like token claimers or token creators) and token-type agents. The FIN4 simulation code is open source and is based on time steps, using cadCAD,⁵ an open-source tool for “complex adaptive dynamics computer-aided design”. At every time step, key variables are updated through actions or policies.

In addition to being sustainable and scalable, the FIN4 system should also be resilient to unintended user behavior. We use simulations to improve the cryptoeconomic design towards system stability and to avoid dynamics that may result from not fully accounting for the “human factor.”

Our definition of an ideal stable system includes token creators with noble intent, tokens invulnerable to manipulation and users using tokens as intended. In contrast, bad situations can occur due to token creators with malicious intent, tokens vulnerable to manipulation, or users cheating.

The simulation configuration allows one to study groups of human users as agents with certain predefined attributes (e.g., intentions, compliance with rules or commitments defining a type of token) or with random attributes. To bootstrap a token-based economy in a community, agents can define types of tokens that will be available for claiming or allowing fellow agents to create their own tokens with a certain frequency.

⁵cf. www.cadCAD.org.

Stage	FIN4 Principles	Behavior Expectations	Potential Risks	Mitigation Strategies
0	Anyone can access	Many join, users join in bursts (entire communities)	Users flood system with "fake accounts" (sybil attack on access)	Decentralized blockchain: each user needs wallet and crypto for using FIN4
1	Anyone can obtain Positive Action Tokens (PATs)	Many different PATs are obtained, a multi-dimensional incentive system unfolds and develops	Users cheat to enrich themselves with PATs	Proof mechanisms: users need to prove to the system that they did actions
2	Anyone can create Positive Action Tokens	Dynamic, obtaining tokens happens more often than creating tokens	Spam of PATs in general, spam of malicious PATs	Token Registry: users co-curate list of trustworthy PATs (GOV token needed)
3	Anyone can curate Positive Action Tokens	Committed users successively gain influence to co-govern FIN4 system by accumulating GOV tokens.	Users hoard GOV tokens to self-promote own PATs, attack other PATs in teams, or try to amass power.	Individual Reputation: no matter their PAT wealth, users need to build reputation over time to receive GOV tokens. Bad behavior results in reputation loss. (REP token needed)

Fig. 10 Elements of an iterative simulation concept for the Finance 4.0 system with tokens representing positive action (PAT), reputation (REP), or governance (GOV)

Figure 10 illustrates the iterative approach that the simulation concept is built on. The simulation follows the natural stages that users encounter when joining the Fin4 system and accounts for the risks that occur at each stage.

The basic principle of FIN4 is that anyone can access the system (stage 0). Depending on their intentions, users may enter individually or as a “cartel” in a coordinated fashion to unduly influence the system. The main safeguard against this is to use blockchain technology: Wallets and keys represent barriers and prevent users from spamming (e.g., auto-registering many fake users).

Once they entered the system (stage 1), users can obtain Positive Action Tokens (PATs) at their own discretion. The core problem here is cheating: Users try to obtain tokens without performing the required actions. Therefore, an extendable set of proof mechanisms is put in place to support the process of proving actions. As anyone is able to create new types of Positive Action Tokens (PATs, stage 2), the system may face a flood of PATs. To navigate the token space and avoid malicious tokens to gain traction, users co-curate tokens and promote the trustworthy ones. As anyone is able to participate in token curation (stage 3), more complex types of malicious behavior are thinkable. To counter them, a reputation mechanism is put in place to steer how users gain power for co-governance over time.

For the evaluation of the system’s state, we identified a series of behavioral and design parameters and visualized them as dimensions of a three-dimensional parameter space (see Fig. 11).

Obtainer compliance: “1” means that token obtainers respect and fulfill the token proof type according to the demands of the token creator. “−1” means that all the

Fig. 11 Token design space of the Finance 4.0 system

users find a way to claim the token without doing the action for it, by finding the weak spot of the token proof mechanism and exploiting it.

Token robustness: “1” means that the design of the token proof is so good that it has no weak spots that can be exploited, yet it is simple enough not to hinder users in claiming. “-1” means that the token proof mechanism is flawed and individuals can claim tokens without performing the action the token was created for.

Creator intent: “1” means that the token creator has noble intent when creating the token, e.g., for slowing down climate change, feeding the poor, saving endangered species, etc. “-1” means that the token creator is malicious (usually focused on personal gain), intending, for example, the exploitation of users, the manipulation of public opinion or the destruction of private property.

The “Ideal” region of the parameter space represents the best case in which the users are compliant, the token types have robust proof mechanisms and the intention of the token creator is noble. The “Compliant Community” area is equivalent to the “Ideal” case only when all users are compliant. The “Danger Zones” correspond to worst-case scenarios. They are characterized by the malicious intent of the token creator that can be hidden from the token claimers. On the other hand, the “Road to Hell” area contains tokens created with good intentions that are abused or misused by the community. The “No Takeoff” regions and the “Swamp Area” lack compliance of the users.

At this stage of the simulations, the token types created are mapped to the parameter space according to their attributes (robust or weak design) and the community profile (compliance and intention). So far, the picture is a static one. The next steps are to introduce reputation (and governance) tokens and the Token Curated Registry (TCR). Once human agents will vote for token types according to their interests (using GOV tokens) and will challenge official tokens for the sake of the community (using the TCR), the static picture will become dynamic and PAT types will move from one area in the parameter space to another. Our goal is to study these dynamics and to figure out how we can keep tokens out of the “Danger Zones” and create traction towards the top right corner (“Ideal”) (Fig. 11).

In our point of view, the governance of a decentralized system should be based on trust and experience. In order to select the people who will obtain the power to vote on official tokens, we propose constructing a trust network in the community using reputation tokens (REP). Once the network is vast enough (measured in terms of nodes and links between nodes), we focus on key nodes in the newly formed network: the nodes most connected directly to other nodes (Total Degree Centrality), the interfaces between groups (Betweenness Centrality) and the most influential/powerful actors according to the network (Eigenvector Centrality).

The Finance 4.0 Technology Landscape

The Finance 4.0 Architecture

In order to contribute to solving real-world sustainability issues, our ambition was also to lay the groundwork of a system that can survive and thrive under real-world conditions, applying system engineering methods.

As a first step towards developing a demonstrator platform, a series of workshops was conducted, aiming at compiling an initial list of requirements.

Two expert workshops were organized in 2018 to examine a range of specific challenges. A proving workshop in Zurich covered topics relating to the design and use of oracles, while a cryptoeconomics workshop in Berlin discussed some of the decisions made for the incentive system.

Based on the results of the requirements phase and the workshops, a functional architecture was developed to describe the core functionality of FIN4 (see Fig. 12).

The system architecture consists of three main layers (bottom to top):

- **A blockchain layer:** The blockchain including the smart contract engine serves as backbone to make FIN4 a decentralized, peer-to-peer platform. Transactions, data on smart contracts and balances on tokens are stored immutable and tamper-proof on the blockchain ledger.
- **A smart contract layer:** FIN4 smart contracts get deployed onto the blockchain. They comprise both the operation logic and the storage of most of the data. All of the functionality lies here and is accessible even from outside the FIN4 application.

Fig. 12 Functional architecture of the Finance 4.0 system

While most data is stored directly on the contracts, media files provided to proof claims (e.g., a picture of a planted tree) are uploaded to the Inter-Planetary File System (IPFS), and only their identifiers are stored on the smart contract. The claims pool is not yet implemented.

- **An application layer:** The purpose of the application layer is to interface with end users—typically via Web or mobile applications. While a default client for both Web and mobile is provided, third parties can also interface with the system by building their own clients. Thus, they can limit the functionality that the FIN4 smart contracts provide. Extensions to the FIN4 core system, however, can only be made on the smart contract layer.

Suitable programming languages and frameworks have to be defined to implement this functional architecture. For the smart contract engine and blockchain layer, we chose the Ethereum platform.⁶ Ethereum is a relatively widespread and established smart contract engine, with a large community of developers and projects, as well as a broad range of development tools.

The FIN4Xplorer is running on the Rinkeby test net.⁷ There are currently no plans to make the demonstrator available on Ethereum’s main net, as high costs would incur and there would be no immediate gains in functionality or performance. However, projects that follow on from FuturICT 2.0 in the future may choose to take this route.

The FIN4 smart contracts are written in the Solidity programming language⁸ and deployed using Truffle⁹ as a framework and Infura¹⁰ as a provider.

The FIN4 client we provide is a Web application written in JavaScript¹¹ using the React library.¹² The layout is optimized for viewing on both desktop and mobile

⁶cf. <https://ethereum.org/>.

⁷cf. <https://rinkeby.io>.

⁸cf. <https://soliditylang.org/>.

⁹cf. <https://trufflesuite.com/>.

¹⁰cf. <https://infura.io/>.

¹¹cf. <https://javascript.com/>.

¹²cf. <https://reactjs.org/>.

browsers, which are Web 3.0-enabled. All is currently hosted on Amazon Web Services.¹³

Earlier setups with Internet of Things devices as proof type used a Node server¹⁴ to receive the signals from the sensors and forward them to a smart contract, acting as an oracle. The respective code from the github repositories FIN4OracleEngine and FIN4Sensor can be modified to connect other IoT devices.

The Finance 4.0 Development Phases

The FIN4 demonstrator software, called FIN4Xplorer, progressed through several development phases before reaching its current state.

Phase 1: The “Slick but Centralized” (SLIC) Release

Our initial version (developed by Quasi Jouda) performed all blockchain interactions via a server. This architecture offered the convenient, demo-friendly advantage that users could sign up easily (with just a nickname) and participate in creating and claiming tokens within moments of accessing the Web application.

The drawback, however, was that it did not live up to the standards of a distributed project. The use of a centralized server and the custody of users’ private keys create vulnerabilities to attacks, while also teaching new users a flawed concept.

We had the responsibility to get it right, since many of our users’ first contact with blockchain technology would be through our DApp. Setting up and using a crypto wallet that the users can control was, therefore, important.

Phase 2: The “Fabulous Five” (FAB5) Release

A team of five volunteers (Simon Zachau, Benjamin Degenhart, Kriti Shreshtha, Sangeeta Joseph and Leon Kobinger) completely re-implemented the system to come up with a fully decentralized solution. Their task was to focus on the mechanisms required to link a positive action in the real world to a token balance—i.e., the steps for making claims that are proven in several different ways.

Phase 3: The “Explorer” (XPLR) Release

One member of the “Fabulous Five” (Benjamin Degenhart) continued to work on the system. This phase saw the introduction of more new features including the

¹³cf. <https://aws.amazon.com/>.

¹⁴cf. <https://nodejs.org/>.

ability to create user groups, token collections, messages and an own Ether faucet (so users could easily request Ether) and QR codes, as well as transfer token balances. Furthermore, the following four major contributions were integrated.

The first contribution (by Gabriel Hirschbaeck) was a generic smart contract from which different base versions of positive action tokens can be derived in accordance with the taxonomy [21]. Supporting these base versions was a key step towards enabling the breadth of token economies we envision.

The second contribution (by Sergiu Soima) came in the form of the Token Curated Registry (TCR) [22]. A TCR allows an anonymous group of economically incentivized users to maintain a list of entries by submitting votes or challenges. We use this mechanism in our governance layer for maintaining a list of Official Position Action Tokens.

The third contribution (by Piotr Chodyko, Moritz Schindelmann, John Rachwan, and Ling Zhu) redesigned the proving mechanism and created a systematic taxonomy to classify verifiers and implemented an integrated verification system with multiple types of verifiers and decentralized proof of storage [23].

The fourth contribution (by Kriti Shreshtha) was new functionality that allows to incentivize entire communities/collectives rather than just individual users [24].

The Finance 4.0 Demonstrator

As a typical Web3.0 application, FIN4Xplorer¹⁵ consists of two parts: (1) smart contracts on the Ethereum blockchain required for all functionality that should be run in a decentralized, immutable manner and (2) a front end or Decentralized App (DApp) client that serves as a Web interface to the smart contracts. The Ethereum blockchain was chosen as it meets the requirements as an open-source, public blockchain that supports smart contracts. Since it is widely used, one can find much documentation and online resources as well as tap into a large and active developer community.

A user can simply connect to the live version of our demonstrator by visiting <https://demo.finfour.net>.

From a user perspective, the key difference between a Web 3.0 DApp and a Web 2.0 service is the need for a bridge to the blockchain: a crypto wallet. The first task of a crypto wallet is to connect to the blockchain network, either via a full node run by users themselves or via a gateway service like Infura.¹⁶ Its second task is to appear whenever the user wishes to write data to the blockchain. The recommended crypto wallet to connect to the FIN4 system is MetaMask,¹⁷ which is available both as a browser extension for the desktop (Chrome, Firefox, Opera and Brave) and as a mobile App (iOS and Android). With a crypto wallet, the user can follow the steps to

¹⁵Source code available at <https://github.com/FuturICT2/>.

¹⁶cf. <https://infura.io/>.

¹⁷cf. <https://metamask.io/>.

create a new account—or restore an existing account. To connect to FIN4, the user needs to switch from the Main Ethereum Network to the Rinkeby Test Network.¹⁸

The last step before starting is to acquire free Rinkeby Ether tokens by using either

- the authenticated faucet at faucet.rinkeby.io (in exchange for a public social media post you receive some Ether tokens);
- the FIN4 faucet server available for users on the demo.finfour.net landing page. For this, click the button [Request Ether] and wait for confirmation.

If FIN4 is migrated to the Ethereum main network in the future, real Ether tokens (ETH) will be required for writing transactions to the blockchain. Such tokens cannot be received from faucets for free; they have to be earned through mining or bought at exchanges with cryptocurrency or fiat money.

Information Box: Web 3.0 Technologies Used in Finance 4.0

The smart contracts are written in Solidity¹⁹ and deployed on the Rinkeby testnet²⁰ via Truffle.²¹ Rinkeby is suitable for the development stage as it uses freely available tokens—unlike the Ethereum main net which requires tokens obtained through exchange or mining. We simulate the Ethereum blockchain using Ganache from Truffle.²² To store media files required by certain proof types, we use IPFS²³ via the Infura gateway.²⁴ The MetaMask crypto wallet²⁵ allows users to connect desktop or mobile browsers to the Ethereum network. The frontend is a React app²⁶ that uses Drizzle from Truffle²⁷ to connect to the smart contracts on Ethereum.

Learn more about the Web3.0 development tool chain at <https://fin4xplorer.readthedocs.io>.

After successfully connecting to the FIN4 DApp, the user should see the Home screen (Fig. 13). From there, you can access the Tokens and Claims tab from the navigation bar at the bottom. The three icons in the top right enable users to display a QR code of their token account, refresh the page and show notifications.

¹⁸cf. <https://rinkeby.io/>.

¹⁹cf. <https://soliditylang.org/>.

²⁰cf. <https://rinkeby.io/>.

²¹cf. <https://trufflesuite.com/>.

²²cf. <https://www.trufflesuite.com/ganache>.

²³cf. <https://ipfs.io/>.

²⁴cf. <https://infura.io/>.

²⁵cf. <https://metamask.io/>.

²⁶cf. <https://reactjs.org>.

²⁷cf. <https://trufflesuite.com/drizzle>.

Fig. 13 Main screen of the Finance 4.0 DApp (available at <https://demo.finfour.net>.)

The Tokens tab allows users to create new tokens, as well as view further information about how they work and how to claim them. Viewing a token opens a dedicated page showing details about the design and performance of the token.

The token creator takes the user step by step through the process of creating a new ERC-20²⁸ token, or “Positive Action Token.” Alongside some basic information like a name, a 3 to 5 character long symbol and a description as well as various fundamental properties of the token design have to be specified, which define the economy that can revolve around this token later on. Furthermore, verifiers are added here that define the proofs user have to provide in order to successfully claim this token. None of the choices a token creator makes in this process can be undone—that is why it is important to think carefully about how to design the new token.

The Claims tab follows the same layout as the Tokens tab. Here, you can submit new claims and view a list of previous claims. “Claiming” is the process of saying

²⁸cf. <https://eips.ethereum.org/EIPS/eip-20>.

that you did a positive action in the real world and want the respective token for it. If the claim can be automatically verified, the transfer of the respective token happens immediately, otherwise only upon successful delivery of the necessary (manual) proofs that are required from the claiming user.

For governance, the FIN4 system currently offers a Token Curated Registry (TCR) that allows to collectively manage Positive Action Tokens (PAT). When they collected enough reputation (REP), users can claim governance tokens (GOV) for their reputation tokens (REP). Using the same mechanism, users can collectively change the rules of the token registry by voting on parameter changes. Users with enough governance tokens (GOV) can curate the list of Official Positive Action Tokens (OPATs) in the token curated registry.

Other features for communities are token collections and user groups. Token collections are an easy way to access a predefined list of existing tokens. The feature “user groups” allows one to define user groups for managing token collections and for determining participants in social verification mechanisms.

Finally, a basic messaging system allows users to send messages to each other pseudonymously.

The Finance 4.0 Governance System

FIN4 aims to create an open-source, distributed platform for communities willing to incentivize sustainable actions. Sustainability, privacy and individual freedom are key to the platform. FIN4, therefore, incorporates different types of identity and distributed governance on multiple levels.

But how do participants identify themselves? To what extent can reputation replace identity? How can we prevent malicious use and inadequate accumulation of power? And how can we assure participation in governance and meaningful debates?

These questions are far from trivial and can be approached from different perspectives. Certainly, further research is needed before large-scale deployment of the FIN4 system is advised.

Blockchain Governance and Practical Implications

Code—and any implementation of blockchain-based governance—is always embedded in a social context. Every distributed ledger technology (DLT) project is nestled in a political reality, with laws and decision-making procedures, and cannot be seen as fully independent. Whenever we talk about on-(block)chain governance within FIN4, we see the decisions taken as part of a greater social system. And these actions and decisions are bound to the same rules, laws and regulations as other projects.

Fig. 14 Potential governance framework for FIN4

Nevertheless, blockchain-based systems allow one to support a power shift from centralized top-down governed structures to federated, self-organizing, bottom-up communities, which do not simply try to cement the status quo.

In the case of FIN4, our goal is to implement a direct democratic voting system linked to the reputation system which is inherent to the platform. Reputation tokens lead to voting rights that can be exercised in all kinds of decisions at different levels—from token curated registries to substantial decisions about the future direction of FIN4.

A number of issues need attention when translating reputation tokens into voting tokens. First, we want reputation to influence voting power. Users with a longer history of honest interactions in the system should enjoy more power. But how much more? To prevent an unbalanced distribution of power and a dictatorship of a group of people, we propose two mechanisms: quadratic voting and a hard cap on reputation tokens. What is more, voting tokens used for voting on system parameters and functions are not returned to users, but instead “burned.” This means users would have to carefully consider when to spend voting tokens, since using them means they are gone.

For decisions with a smaller scope, such as voting on which tokens to include in the Token Curated Registry (TCR), one could introduce another type of token—TCR tokens. These could have different qualities compared to the voting tokens above. For example, they may be uncapped and returned to users winning a vote. They could also be transferable.

Voting pools could represent different communities and would help to ensure that the users are not overwhelmed with too many voting options (Fig. 14).

Governance Layer

The governance layer is required to align user incentives towards the creation and maintenance of token economies. It offers mechanisms that allow users to collectively decide on which tokens to include as official FIN4 tokens and which ones to

Fig. 15 Staking and voting as basic mechanisms of a Token Curated Registry (based on [25])

reject (first order governance in Fig. 14). On a higher level, the system offers on-chain governance—the possibility for users to collectively change the governance rules (second order governance in Fig. 14).

Any system that permits users to submit new token proposals will sooner or later face the problem of how to deal with spam or malicious tokens. Rather than erecting rules or barriers to restrict token creation, our design utilizes the innovative capacity of independent token proposals. Every token idea is welcome, but adoption as an official FIN4 token requires a sufficiently large share of users to approve the proposal. Based on democratic decision procedures, approvals may also be withdrawn. In any case, the users would collaborate to co-maintain a list of official FIN4 tokens in a Token Curated Registry (TCR) (Fig. 15).

Reputation

The purpose of the reputation tokens (REP) is to help pseudonymous users trust each other in order to interact effectively on the platform. Reputation reflects the positive, platform-sustaining actions performed by a user. These actions can include the active gathering of positive action tokens (zero or low REP reward), participating in proof mechanisms or certain governance mechanisms (medium reward) and successfully proposing official tokens (high reward). In addition, developers should be able to get reputation rewards for contributing to the technical development of the platform.

It should also be possible for users to lose reputation tokens, especially if they interact with the system in a fraudulent way, e.g., by giving false testimony in a social-proof mechanism. However, these mechanisms are still under development.

Tokens based on reputation—as the “qualified money” idea suggests—sometimes raise concerns. However, it is important to realize that money is already judged in

this way when we shop online. Factors such as location, type of computer, and other personal qualifiers are used to discriminate among different kinds of online consumers and offer them different prices. Therefore, reputation systems already interfere with our current economic system. FIN4 utilizes reputation not as a mechanism to discriminate against users, but to discourage bad actors and thereby secure a healthy platform. What is more: its opt-in nature and democratic voting give it legitimacy.

Identity

Our idea is to keep the system open, so users can connect different digital identities they have from other providers. Within the FIN4 system, a username linked to an Ethereum address and a reputation score would be already sufficient to establish an identity (ID). But if FIN4 should also allow you to receive tokens tied to a specific citizenship or residency (such as local recycling tokens that may be turned into free museum admission), one could imagine using other forms of IDs to validate claims to certain tokens. It may be beneficial if the system were compatible with both, completely self-sovereign and government-validated digital identity systems.

The ultimate goal of FIN4 is to develop a system design that maximizes privacy (through participation based on self-sovereign digital IDs) and that ensures equality (through caps and quadratic voting), honesty (through reputation) and participation (through easy accessibility).

Proof Mechanisms

Our goal is to create an open-source, distributed platform that allows communities to incentivize sustainable actions using positive action tokens. Users can browse the available FIN4 tokens and see which actions can be carried out in order to earn the respective tokens. After performing the relevant action (planting a tree, collecting litter, or similar), the users need to submit a proof that they actually completed the required action.

But how to prove actions? How can one incentivize users to report actions truthfully? And how can one ensure reliable data is delivered by sensors? This is where proof mechanisms come in.

Token creators on the FIN4 platform will be able to choose from a range of default proof mechanisms for their incentivized actions. These proof mechanisms could include social proofs—requiring *other* platform users to verify user claims—as well as sensor proofs and oracles based on third-party data. Combinations are also possible.

Whenever we need to prove something—in everyday life or within the FIN4 system—there is a trade-off between certainty and usability. With FIN4, proving actions represents a particular challenge. A good balance needs to be found between

the effort required and the certainty of proving activities. These proof mechanisms also need to be carefully adapted to each individual token type. For example, a token for promoting a reduction in noise level will use different proofs (including sensors) compared to a token for community cleanup events (removing litter from a public park, for example).

One proof type is the *sensor proof*, which is based on a direct measurement of sustainability data. It requires the least human input and can potentially democratize the provision of and access to data, thereby promoting the value of decentralization while also maximizing efficiency in the proof process. Ideally, data fed into FIN4 should come from these direct measurement sources. Social proofs would only come into play whenever objective measurements are unavailable. Third-party data could be used where data cannot be generated directly within the FIN4 system.

Combinations of proofs will be required to make it more difficult to game the system. Redundancy can be used to increase the reliability of proofs. This is also true in the case of sensors, where a single measurement device may display errors.

With *social proofs*, we generally rely on a testimonial provided by an individual or a sample of typically unrelated people. While users may be able to testify for themselves (auto proof), using a password, signature or similar, we mainly want to work with testimonials provided by peer users. The more users testify to a claim, the more reliable the social proof usually becomes. However, one needs to consider the costs of multiple verifications, which reduce the efficiency of the system. Therefore, social proofs should be straightforward, so random users can do the verification.

Both individual and social proofs can be based on location certain roles or skills, but do not have to. Testimonial power can also be linked to user reputation. But what happens if two validators do not agree? A third validator with a high reputation could be involved to act as a tie breaker. The third validator as well as the one they agree with would receive the regular reputation tokens. Conversely, the user who had submitted false evidence would lose reputation tokens. However, the defeated validator may appeal the decision, putting more reputation tokens at stake. An additional validator would then be called upon to be the judge, with the process continuing in this way if further appeals are submitted.

Honey pots involving fake proof tasks could also be used to catch bad actors and decrease their reputation tokens. These mechanisms may help maintain the integrity of the FIN4 system, while also striking a balance between usability and reliability (see Fig. 16).

Research Outlook: Long-Termism

The first studies and software developments connected with the FIN4 project were initiated by FuturICT 2.0—a FLAG-ERA project supported by the Swiss National Foundation (SNF). FuturICT 2.0 created related concepts, released an initial software demonstrator and spread the idea in academia and beyond (cf. Fig. 17).

Fig. 16 Type of measurement decides the type of proof mechanisms

FIN4Plus and FIN4Xplorer were two follow-up projects that were supported by EIT Climate-KIC. They initiated a co-design process where the ideas and concepts entered the EIT Climate-KIC strategy for running demonstrations. In that phase, the initial demonstrator software was completely overhauled, improved and extended, thereby incorporating all the different modules into a single, coherent and decentralized demonstrator application ready for small-scale, experimental use.

Fig. 17 Finance 4.0 platform evolving across various research projects

We hope to be able to test the FIN4Xplorer application in a series of experiments with real communities, generating feedback from users to help refine the software design and functionality. This would enable a subsequent release based on these insights.

The goal is to be ready to apply the concepts and application to larger-scale experiments, e.g., in the EIT Climate-KIC “Deep Demonstrations on Long-Termism” program.²⁹

Systems Innovation. In their strategy document 2019–2022, EIT Climate-KIC argues that innovations at the system level are key to advance the sustainability transformation. Systems innovations refer to “integrated and coordinated interventions in economic, political and social systems and along whole value chains through a portfolio of deliberate and connected innovation experiments” [26]. The proposed approach of using a portfolio of experiments is designed to produce viable pathways towards change by identifying options as well as social and behavioral inflection points and scaling transformative solutions.

Deep Demonstrations. Demonstrating potential for change is central to the transformation needed and for providing inspirational examples of what is possible. These start with a demand-driven approach, working with city authorities, regional bodies, governments and industry leaders, committed to a transformation to net zero emissions and a resilient future. EIT Climate-KIC has initiated eight deep demonstrations to cover a wide range of challenges.

Long-Termism. The design group has co-designed a portfolio of connected experiments that are ready to be planned out and implemented. As part of the design group, we contributed concepts for building incentive systems that promote sustainable action and can serve as basis for sustainability-driven basic income schemes—on the basis of the Finance 4.0 framework.

Over the course of the project, relationships with several organizations and communities have been established to enter the next phase of experimentation:

- The *KISS Foundation*³⁰ wants to bring their social time-banking scheme online;
- *WWF Romania*³¹ aims to prevent poaching with novel incentive systems;
- The *Red Cross* is working on community inclusion currencies;
- *Haus der Materialisierung* (Berlin)³² promotes circular economy communities;
- *wertfrei*³³ is a platform promoting inclusion and sustainability.

With some organizations, several initial prototypes have been developed during week-long blockchain hackathons for sustainability. Those prototypes can be found online:

- <https://github.com/FuturICT2/BETH-2019>
- <https://github.com/FuturICT2/BIOTS-2018>.

²⁹cf. <https://www.climate-kic.org/programmes/deep-demonstrations/>.

³⁰cf. <https://fondation-kiss.ch/>.

³¹cf. <https://wwf.ro/>.

³²cf. <https://hausderstatistik.org/hdm/>.

³³cf. <https://wertfreiplattform.ch/>.

Summary

The world today faces a range of major sustainability issues: global inequality, financial crises, over-consumption and conflict for natural resources.

By now, there are some common goals with respect to sustainability, as formulated in the United Nation’s Sustainable Development Goals and the Paris Agreement. Agreeing on a joint set of goals in a supranational context is certainly important. However, it represents just a first step in a longer transition, because we still face a misalignment of goals and incentive structures.

Therefore, we propose a new approach to achieve sustainability, based on voluntary individual contributions and collective action incentivized by local, real-time feedback (Fig. 18). If we compare the options—a data-driven, AI-controlled society on the one hand and a digitally empowered participatory society on the other hand—the latter is perhaps harder to reach. However, it is expected to be more resilient and more successful in the long run than a top-down controlled society—and more rewarding.

	Top-down Steered Society	Enabled Participatory Society
Decision making	central	distributed
Strategy	big data / machine learning	co-creation / collective intelligence
Operational mode	top-down orders	MOODs
Resource use mitigation	surveillance, citizen score	positive incentivitation
Personal freedom	severely limited	maximized

Fig. 18 Two different approaches to the digital society

With the FIN4 system and the associated demonstrator, FuturICT 2.0 has shown that it is technically feasible to introduce a distributed system incentivizing sustainable action. At numerous events and during the first edition of the Climate City Cup,³⁴ a lot of scientists, companies and individuals around the world have demonstrated their interest in this approach. In subsequent projects that will further extend the FIN4 concept, new partners are expected to join the movement and help establish this novel, participatory approach towards the creation of a more sustainable world and a peaceful, prospering society.

Author Contributions

Mark Ballandies contributed to the sections on Framework and Cryptoeconomics as well as Figs. 5, 7 and 8.

Marcus M. Dapp contributed to the sections on Framework, Cryptoeconomics, Technology Landscape, and Research Outlook as well as Figs. 2, 4, 5, 9, 10, 12 and 17.

Benjamin Degenhart contributed to the section on Technology Landscape as well as Fig. 13.

Dirk Helbing developed ideas and strategies for the FuturICT 2.0, Finance 4.0 and Climate City Cup frameworks. He contributed the Abstract and provided various edits and feedbacks.

Stefan Klauser contributed to the Preface of the Finance 4.0 book, the sections on Ambition, Governance System, and to the Summary as well as Figs. 1, 3, 14, 16 and 18.

Anabel-Linda Pardi contributed to the simulation parts mentioned in the Cryptoeconomics section as well as Figs. 10, 11.

Acknowledgements Herewith, we would like to thank everyone who has contributed to the Finance 4.0-related work. The following people, in particular, listed below in alphabetical order, have significantly supported the project at various stages of its concept, design and implementation phases in the past few years: Fatime Ahmeti, Piotr Chodyko, Leonie Flückiger, Thorben Funke, Gabriel Hirschbaeck, Sangeeta Joseph, Qusai Jouda, Leon Kobinger, Anabele-Linda Pardi, Evangelos Pournaras, John Rachwan, Max Rößner, Moritz Schindelmann, Kriti Shreshtha, Alexander Stein, Sergiu Soima, Magnus Wuttke, Simon Zachau, and Ling Zhu.

The authors are also grateful to Dian Balta and his team at TU Munich for the great cooperation in teaching and the joint supervision of student projects.

Lewis Dale and Eoin Jones have provided excellent copy editing support, and Anna-Lena Stach at Relevance House has significantly contributed with her graphical designs and layout of the ebook (technical report), on which this book chapter is based.

Work on the Finance 4.0 system has been financially supported by the Swiss National Science Foundation (Grant No. 170226) as part of the European FLAG ERA project “FuturICT 2.0 – Large scale experiments and simulations for the second generation of FuturICT” (<https://futurict2.eu/>).

³⁴cf. <https://climatecitycup.org>.

In addition, work reported in the research outlook and the demonstrator were supported by EIT Climate-KIC (Grant Nos. 191170, 191354 and 200994) as part of the “Deep Demonstrations on Longtermism” program and the “Thought-Leadership” program (<http://www.finfour.net/>).

References

1. H. Schandl, M. Fischer-Kowalski, J. West, S. Giljum, M. Dittrich, N. Eisenmenger, A. Geschke, M. Lieber, H. Wieland, A. Schaffartzik, F. Krausmann, S. Gierlinger, K. Hosking, M. Lenzen, H. Tanikawa, A. Miatto, T. Fishman, J. Ind. Ecol. **22**, 827 (2018)
2. M.C. Urban, Science **348**, 571 (2015)
3. UN General Assembly, *Transforming Our World: The 2030 Agenda for Sustainable Development* (Division for Sustainable Development Goals, New York, NY, USA, 2015)
4. Conference of the Parties, *Adoption of the Paris Agreement* [U.N. Doc. FCCC/CP/2015/L.9/Rev.1] (2015) <https://documents-dds-ny.un.org/doc/UNDOC/LTD/G15/283/19/PDF/G1528319.pdf>
5. M.C. Ballandies, M.M. Dapp, E. Pournaras, Decrypting distributed ledger design—taxonomy, classification and blockchain community evaluation. Cluster Computing (2021). <http://doi.org/10.1007/s10586-021-03256-w>
6. V. Buterin, *Introduction to Cryptoeconomics* (2017) <https://www.youtube.com/watch?v=pKq djaH1dRo>. Accessed 23 Dec 2020
7. H.C.A. van Tilborg, S. Jajodia (eds.) *Encyclopedia of Cryptography and Security*, 2nd edn. (Springer, US, 2011)
8. M. Zargham, *Creating Interconnected Collaborative Communities* (2018) <https://www.youtube.com/watch?v=nOP6anxiHkk>. Accessed 23 Dec 2020
9. M. Dobler, M. Ballandies, V. Holzwarth, On the extension of digital ecosystems for SCM and customs with distributed ledger technologies, in: *2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (2019). <https://doi.org/10.1109/ICE.2019.8792646>
10. K. Wüst, A. Gervais, Do you need a blockchain?, in: *2018 Crypto Valley Conference on Blockchain Technology (CVCBT)* (2018), pp. 45–54
11. R.N. Mantegna, J. Kertész, Focus on statistical physics modeling in economics and finance, New J. Phys. **13**, 025011 (2011)
12. T. Lux, Applications of statistical physics methods in economics: Current state and perspectives, Eur. Phys. J. Spec. Top. **225**, 3255–3259 (2016)
13. A. Sinha, S. Mukherjee, B.K. Chakrabarti, Econophysics through computation, Journal of Physics Through Computation **3**, 1–54 (2020)
14. M.H.R. Stanley, L.A.N. Amaral, S.V. Buldyrev, S. Havlin, H. Leschhorn, P. Maass, M.A. Salinger, H.E. Stanley, Nature **379**, 804 (1996)
15. S.-H. Chen, S.-P. Li, Econophysics: Bridges over a turbulent current, International Review of Financial Analysis **23**, 1–10 (2012)
16. R. Kutner, M. Ausloos, D. Grech, T. Di Matteo, C. Schinckus, H.E. Stanley, Physica A: Statistical Mechanics and Its Applications **516**, 240–253 (2019)
17. D.D. Gatti, S. Desiderio, E. Gaffeo, P. Cirillo, M. Gallegati, *Macroeconomics from the Bottom-Up* (Springer, Mailand, 2011)
18. D. Helbing (ed.), *Social Self-Organization: Agent-Based Simulations and Experiments to Study Emergent Social Behavior* (Springer, Berlin Heidelberg, 2012)
19. F. Abergel, H. Aoyama, B.K. Chakrabarti, A. Chakraborti, A. Ghosh (eds.) *Econophysics of Agent-Based Models* (Springer International Publishing, 2014)
20. C.M. Macal, M.J. North, Agent-based modeling and simulation: ABMS examples, in: *Proc. of the 2008 Winter Simulation Conference* (2008), pp. 101–112

21. G. Hirschbaeck, Software Application to Create General-Purpose Tokens on a Distributed Ledger, Bachelor Thesis, University Foundation San Pablo CEU, 2020. <https://doi.org/10.13140/RG.2.2.35923.81447>
22. S. Soima, A Blockchain-Based System for Decentralized Curation of Finance 4.0 Tokens, Master Thesis, Technical University Munich (2020). <https://doi.org/10.13140/RG.2.2.11484.33921>
23. R. John, P. Chodyko, in: *Artificial Intelligence for Cyber Security—Methods, Issues and Possible Horizons or Opportunities*, ed. by S. Misra and A.K. Tyagi. (Springer International Publishing, Cham, 2021)
24. S. Kriti, A Blockchain-Based System to Incentivize Collective Sustainable Behavior in A Community, Master thesis, Technical University Munich (2020)
25. D. de Jonghe, G. Dhameja, T. Debus, G. Pancar, *Curated Governance with Stake Machines*. <https://medium.com/@DimitriDeJonghe/curated-governance-with-stake-machines-8ae290a709b4>. Accessed 23 Dec 2020
26. EIT Climate-KIC, *Transformation, in Time* (2019) <https://www.climate-kic.org/news/transformation-in-time/>. Accessed 23 Dec 2020

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.