Finance 4.0 Concept (Technical Report)

Report

Author(s):
Dapp, Marcus M.; Klauser, Stefan; Ballandies, Mark

Publication date:
2018-02

Permanent link:
https://doi.org/10.3929/ethz-b-000286469

Funding acknowledgement:
170226 - FuturICT 2.0 - Large scale experiments and simulations for the second generation of FuturICT (SNF)

Finance 4.0 Concept

Technical Report

WP3 Interim Report (M12)
February 2018

Marcus M. Dapp*, Stefan Klauser, Mark Ballandies

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* Contact: Computational Social Science, ETH Zurich, Clausiusstrasse 50, 8092 Zurich. mdapp@ethz.ch

File name: D.3.2 Report on Finance 4.0 Concept (M12 report)

1 Introduction[1]

The world faces existential threats as the financial crisis of 2007/8 and its consequences still endanger the stability of economy in Europe and worldwide. Resource shortages are impending. Use of fossil fuels and raw materials has more than tripled in the last 40 years.[2] Climate change may wipe out one sixth of all species.[3] Terror, wars, and migration create increasing challenges. To manage scarce resources and support endangered people, powerful global information systems have been built, based on Big Data and Artificial Intelligence (AI). But at the same time, misuse of Information and Communication Technologies is exploding. The digital automation is expected to claim a large amount of jobs within coming years.

FuturICT2.0 will pursue disruptive innovation by addressing the problems at their root: lack of sustainability. The combination of the Internet of Things (IoT) with Blockchain Technology and Complexity Science creates entirely new opportunities to address our challenges. We propose this under the label "**Finance 4.0**", which stands for a multi-dimensional incentive system to manage complex systems and promote a circular sharing economy to create a high quality of life for more people with less resources. Our current concepts of globalization, optimization, regulation and administration have served us well, but have also reached their limits. For this reason, FuturICT2.0 explores the potentials of complementary growth principles such as co-creation, co-evolution, collective intelligence, self-organization, and self-regulation.

The finance 4.0 system is liberal, democratic, pluralistic, participatory, social and ecological. It makes use of the immaterial nature of information, boosts combinatorial innovation and creates opportunities for all, by fostering an open and participatory production and service ecosystem. Information and communication systems, which empower everyone to take better decisions, to be more creative and innovative, and to coordinate and cooperate with others, would lead to better business models, products and services, smarter cities and smarter societies.

Finance4.0 aims to address global challenges like resource shortages, climate change, economic dislocation, and technical unemployment by building a digital financial system that supports us in achieving the sustainable development goals collectively.

This report highlights the key conceptual ideas and related design questions to build and test a Fin4 system. Chapter 2 describes the conceptual elements in mode detail, chapter 3 provides initial thinking on the architecture from both, an object and a data flow perspective. Chapter 4 explores the evolving technical landscape of blockchain and identifies existing technologies to use as potential building blocks for the fin4 system. Finally, chapter 5 presents a first list of possible use cases for the demonstrator.

1 Excerpts taken from FuturICT2.0 proposal (Horizon 2020 FLAG-ERA JTC 2016 call).
2 BP Statistical Review of World Energy.
3 Mark C. Urban (2015): Accelerating extinction risk from climate change. Science 348:6234, p. 571-573.

2 Conceptual design

The term “Finance 4.0 (Fin4)” represents the continuation of the development from Fintech (Finance 2.0), over blockchain technology (Finance 3.0) to IoT/AI integration (Finance 4.0). While it is still lacking a generally accepted definition, our current understanding sees the following key components of the Fin4 concept:

- the use of a framework to price and trade externalities of different kinds,
- the conceptual framework of a multi-dimensional finance system,
- the possibility of bottom-up creation of money,
- a framework for a suitable feedback and incentive system to enable a favorable (self-)organization of socio-economic systems,
- a circular and sharing economy,
- the possibility of taxation and new opportunities for the ECB to adjust parameters of the financial system, should this be needed.

The concept of Fin4 encompasses a socio-ecological financial system, a new economic system as well as a new social contract. The financial system is target through the installation of a multidimensional system with diverse forms of cryptocurrencies representing all sorts of externalities. The economic system is affected by the new incentivization schemes that influence the patterns of production and consumption to enable a circular and sharing economy. A new social contract is needed when it comes to the format of a supranational governance body for the Fin4 system as well as the set-up of community based decision making schemes that allow for subsidiarity and local and personal individuality.

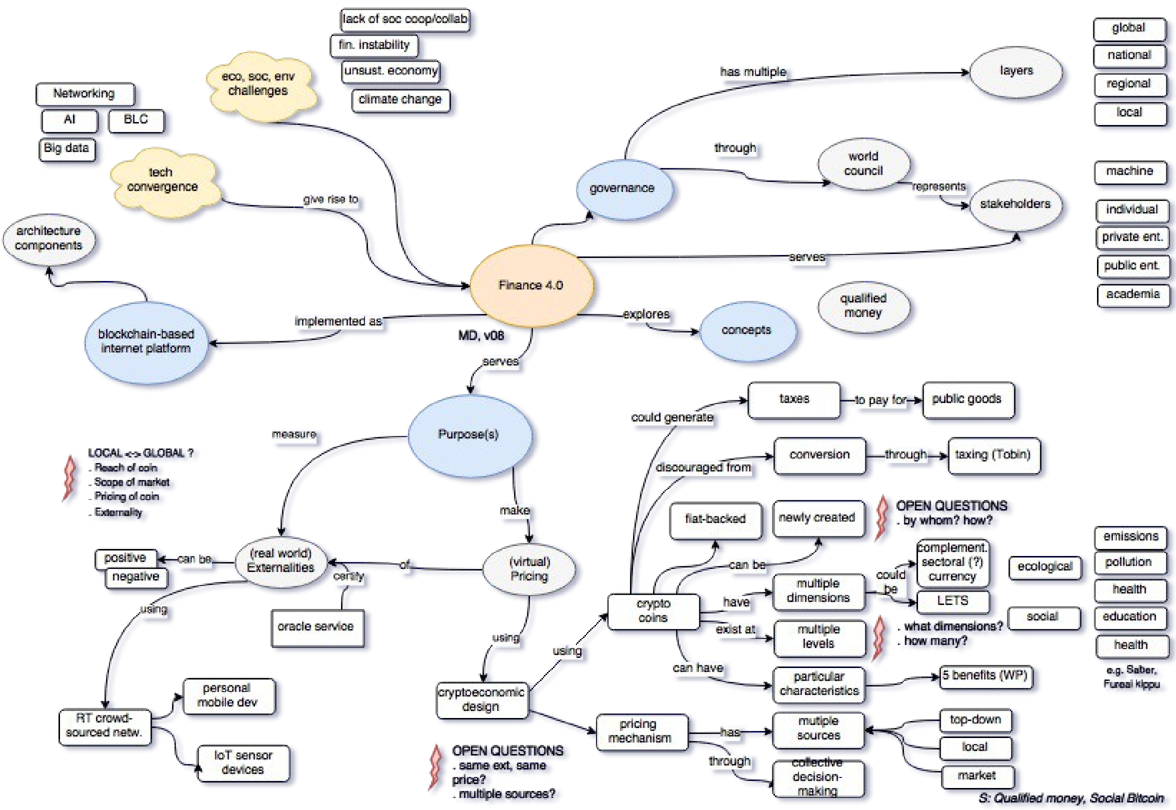

Illustration 1: Initial concept map of the Fin4 system (author’s illustration)

2.1 Pricing and trading externalities

The Fin4 system aims for a self-organizing, nuanced incentive system that supports the daily decision-making of people by encouraging wanted and discouraging unwanted behavior.

In economics, an **externality** is the cost or benefit that affects a party who did not choose to incur that cost or benefit.[4] By giving hitherto unpriced externalities a price and making them tradable, an "internalization of externalities" as economists call it, would happen, and prices would reflect real costs or benefits much closer.

Externalities can be positive or negative and belong to different spheres (ecological, social, etc.). Within the Fin4 system they additionally belong to a level (international, regional, local; c.f section 2.2).

To price and trade externalities requires to measure them in the first place. Such measurements need to be automated for at least two reasons: first, measuring a dozen or more types of externalities can not be done manually. Second, people may tend to tweak their own measurements especially if data is not fully anonymous. How to do automatic measurement of externalities then? The emerging Internet of Things could provide the necessary infrastructure, provided the networks are designed to allow for decentralized, peer-to-peer sharing of data streams. The IoT consists of networks of mobile and stationary sensor devices, for example peoples' smart phones, citizen science projects (e.g. using DIY 3D-printed hardware), as well as infrastructure sensor networks in cities (weather, emissions, etc.). From all these networks data points representing externalities are collected ("measurement") and fed into a price-finding mechanism.

The following table gives some examples of indicator types for ecological externalities that could be of relevance in a circular economy (c.f. section 2.5).

Indicator type	Examples	Availability of data	Relevance to the CE
Sustainable development	Social economic development, sustainable consumption and production, social inclusion, demographic changes, public health, climate change and energy, sustainable transport, natural resources, global partnership, good governance (Table A2)	Voluntary based reporting via EU Directorate-General for Energy (focused), European Sustainable Development Network (ESDN); corporate sustainability indicators (e.g. carbon disclosure)	Natural resources, sustainable consumption and production
Environmental	Agriculture, air pollution, biodiversity, climate change, energy, fisheries, land and soils, transport, waste, water	Regulatory based reporting via EEA cores indicators and country-specific statistics	Waste generated, packaging waste generation and recycling
Material flow	Domestic extraction, direct material consumption, domestic material input, physical trade balance, net additions to stock, domestic processed output, total material requirement, total domestic output	Eurostat, SERI	All
Societal behaviour	Sharing, municipal waste recycle, waste generated per capita (total and segregated), environmental/resource taxation	National and voluntary organisation statistics	All
Organisational behaviour	Material flow accounting in organisations, remanufacturing, use of recycled raw materials, eco-innovation, per capita statistics (e.g. reduction in waste generation per capita)	Private sector voluntary reporting via EU Forum for Manufacturing; ZVEI (German Electrical Industrial Association); VDMA (German Engineering Federation); etc.	All
Economy performance	Resource productivity, recycling industry, green jobs, waste generation/GDP, 'transformation of the economy'	Eurostat EU Resource Efficiency Scoreboard	All

Illustration 2: Exemplary classification of ecological indicators potentially relevant to the circular economy (EASAC 2017, Indicators for a Circular Econonomy, p21)

4 Buchanan and Stubblebine, "Externality."

Different externalities have different geographical scopes of influence. On a global level, for example, humankind as a whole wants to reduce CO2 emissions – a global externality affecting everyone. So, the reduction of emissions, pollution, etc. could be incentivized using a cryptocurrency issued by an inter- or supranational body (e.g., UN, WB, EU, ECB, etc.)

Examples for externalities with a predominantly local effect are noise or some forms of pollution (e.g. fracking). Or on the positive side: when a community wants to increase social cohesion by enabling children to receive education, fostering cooperation and sharing, etc.

In other words, local challenges may vary from place to place. Thus, local communities would need to have the possibility to address local externalities by issuing local currencies serving local purposes, much like the concept of complementary currencies (c.f. section 2.3).

OPEN QUESTIONS IN THIS SECTION

- Convertibility:
  - How would local currencies convert to global currencies?
  - Should locally issued CC be interchangeable across longer distances?
  - Can negative coins (or negative balances) be neutralized through the production of positive externalities? If yes, to what extent? Do we need intended frictions in the system (compare Tobin tax).
- In order to price and trade externalities, they have to be measured in a trustful, secure way. How would this be done?
- How to identify local use case scenarios for the demonstrator application? Criteria could be:
  - needs based on regional/local context
  - strong intrinsic motivation of a local community to solve a local challenge/need
  - extrinsic motivation could be triggered by reputation built into the CC

2.2 A multi-dimensional, multi-layered finance system

We envision a multi-layered, multi-dimensional system of decentralized digital crypto-currencies[5] (CC) created at different levels for different purposes with different characteristics.

Levels are supranational (EU, UN), regional, and local (cities, local communities). **Purposes** address various environmental, social and other kinds of values and costs relevant to the sustainability agenda at the respective level. We use the term "**dimension**" to denote the fact that each "sub-currency" in the wallet of currencies addresses a specific purpose (e.g., reducing waste).

Smart contract software allows to design the characteristics of the digital currencies to fit any purpose and goal ("monetary policy"): from money creation to demurrage to money burning, etc.). Conversion possibilities are also part of that: for some pairings one may want to make conversion more costly than for others (cf. Tobin tax). For example, to which extent should it be

5 A cryptocurrency is a digital asset designed to work as a medium of exchange using cryptography to secure the transactions and to control the creation of additional units of the currency. (Wikipedia)

possible to “balance” ecological costs (e.g. burning the rain forest) with social benefits (e.g. building a school)?

Finally, to be able to establish a flexible multi-dimensional and multi-layered system, the Fin4 concept needs to include the possibility for communities to create their own currencies and design them to address their needs. The next section discusses the creation of money.

OPEN QUESTIONS IN THIS SECTION

1. What experiences with and features of traditional complementary (community) currencies are helpful and suitable for the Fin4 system?
2. How to resolve the inherent tension between top-down currency issuance and the possibility for (local) communities to create complementary currencies? How to regulate this?
3. How do the price finding mechanisms for the different currencies work when both market effects and collective decision making influence the price of a CC?
4. How to approach (central) banks with the idea that other stakeholders would be able to create their own parallel currencies?
5. Could currencies with multiple dimensions on multiple levels increase system stability/resilience?
6. Study possible design principles for CC (deflationary, fiat backed, etc.) and their use in the Fin4 system.

2.3 Bottom-up creation of money

“Money creation (also known as **credit creation**) is the process by which the money supply of a country or a monetary region (such as the Eurozone) is added to. A central bank may introduce new money into the economy (termed "expansionary monetary policy") by purchasing financial assets or lending money to financial institutions. However, in most countries today, most of the money supply is in the form of bank deposits, which is created by private banks in a fractional reserve banking system. Bank lending increases the amount of broad money beyond the amount of base money originally created by the central bank. Reserve requirements, capital adequacy ratios, and other policies are used by the central bank to limit this process.”[6]

Alongside of money creation by central banks and commercial banks, the Fin4 system would in addition allow communities to create their own currency – much like existing schemes of complementary, community, alternative, or sectoral currencies.[7]

In the long run, we envision a hierarchy of currencies. At the top, international organizations like the UN, the ECB or others would issue (and control) digital currencies with global reach, respectively. On national and regional level, national and regional governments could issue currencies with respective reach. At the local level, various kinds of communities could create and issue currencies catering to their local environments and needs.

6 Wikipedia, Money creation.
7 cf. Wikipedia Community, “Local Currency - Wikipedia.”

Although studies[8] show that (local) complementary currencies can be effective in addressing local issues and not hamper the official legal tender currency of a country, some questions need to be addressed.

OPEN QUESTIONS IN THIS SECTION

1. Who would decide what global coins exist? Should a body, like the UN, decide? Should people vote on coin concepts? Who would issue global coins? Do they have to be issued by somebody? The system could just create and distribute them according to a distribution/mining mechanism (cf. steemit).
2. How to reconcile the tension between top-down creation of money by international and national institutions and local, flexible, need-based, "un-monitored"(?) DIY creation of money? What are the risks and what types of local governance would be needed?
3. How to decide upon the convertibility between different coins and thus, the possibility to re-balance between dimensions? How to discourage certain conversions (e.g. Tobin tax)?

2.4 Feedback and incentive system

The proposed framework should also enable a favorable (self-)organization of the overall socio-economic system. While the pricing of externalities aims to guide daily decisions and behavior by people, on another layer, the building of a reputation system based on these transactions would stabilize the mechanism over longer periods of time. Such incentives could support the self-organization of these complex systems and help approach a circular economy over time. Resources would be used more efficiently by promoting social cooperation, environmental and climate protection.

Conceptually, in order to establish something like a reputation rank, the currency underneath needs a "memory". In the simplest form the accumulated sum of coins could express a reputation in that dimension, e.g. a large sum of "HealthCoin". However, as reputation should be built long-term and be less liquid, easy exchangeability of normal liquid coins may not be the right instrument.

OPEN QUESTIONS IN THIS SECTION

1. What concepts of reputation would be feasible? Would the simple accumulation of coins in a sub-currency ("high on SocialCoin") be enough or are more sophisticated metrics needed?
2. What would be the benefits a high positive reputation? A simple public acknowledgment through a rank (e.g. "health 95 points") or receiving privileges in the system akin to more "powers" in a computer game?
3. What role could artificial intelligence play in the sense of reducing complexity of information shown to the user, especially with respect to demand and supply forecasts and other digital assistance services.

8 e.g. H. Nakazato & T. Hiramoto (2012): An Empirical Study of the Social Effects of Community Currencies.

2.5 A circular and sharing economy

Having a Fin4 system in place would allow the gradual building of a circular and sharing economy. **Decentralized** currencies make it possible to install reliable peer-to-peer contracts and allow to create a direct and sustainable sharing economy while adding diversity and decentralization elements to financial markets, which add to their stability.[9]

With circular economy we mean "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."[10]

The (real) sharing economy on the other hand allows people to save basic resources and raw materials through the common use of a utility, tool or other products and assets. Either the use is based on a free to use agreement, a swapping model or the payment of a fee in a peer-to-peer manner.

OPEN QUESTIONS IN THIS SECTION

1. What are the economic effects of a circular and a real sharing economy, especially with respect to employment?
2. How strong does an incentive system have to be to allow a circular economy to build?
3. Would companies be treated differently from private individuals? E.g. could companies be rated according to an index rather than having to balance every coin category in the system?

2.6 Governance

The governance of the Fin4 system have to follow the lines of decentralization and subsidiarity. We argue that any governance system for Fin4 would need to have democratic legitimation on the organizational level. As control at this level wields a lot of power over the people affected, dominance of single players or stakeholder groups needs to be avoided.

This pluralistic approach needs to go all the way down to the technical level as well: changing system parameters, and control over the IoT networks, the AI design, etc. need to undergo democratic oversight. This requires inter alia that all technical artifacts, software, algorithms, APIs need to be open source for public review.

On a supranational coordination level, we propose a council equally consisting of members of the following four stakeholder groups: politics, business, science and citizens. Business sector representatives can be appointed by national or regional economic federations (such as Economiesuisse in Switzerland). Citizen representatives in the World Council would be chosen through regional direct votes. Additionally, States can appoint nationally elected politicians to the politics group. Scientific representatives should be internationally leading experts that cover the scope of fields and disciplines in a balanced way. They are elected by the members of disciplines associations (such as ESSA for Social Simulation). Additional key characteristics of the World Council are regional balance, the absence of veto rights and transparency.

9 cf. Dirk Helbing (2017): Digitization 2.0: A New Game Begins.
10 Geissdoerfer, Martin; Savaget, Paulo; Bocken, Nancy M. P.; Hultink, Erik Jan (2017-02-01). "The Circular Economy – A new sustainability paradigm?". Journal of Cleaner Production. **143**: 757–768.

OPEN QUESTIONS IN THIS SECTION

1. How would the role of central banks on a national and international level need to be adjusted to give guidance and support where needed without hampering the dynamics and innovativeness of local communities?
2. How would technical changes in the design parameters be adopted on all levels? How to do “upgrades” without interfering with the running system?
3. What possibilities, if needed at all, could the system give to central banks (ECB etc.), e.g. new possibilities for taxation systems and adjustments of other system parameters?

2.7 Examples

The range of example for externalities is vast. For illustrative purposes, we present a few examples in this section.

Example for a positive externality: you recycle your car, plant a tree, do community gardening, teach language classes or do any other measurable service beneficial to the community. After giving evidence, you would in exchange receive cryptocurrency in the respective dimension (e.g. “MaterialsCoin, EduCoin, CO2Coin, etc.”). Community tasks could be announced on a decentralized “job” market place. They could become a source of income for “doing good” and may form a part of a basic income scheme.

Example for a negative externality: a community in a city decides – through a collective decision-making process – that they want to sanction (“tax”) noise. The noise level would be measured through an IoT network with suitable hardware sensors and smartphones. So producing noise louder than 100 decibel could e.g. be priced with 2.5 noise coins per minute.

Imagine the following situation: you are about to leave for work in the morning. Based on a real-time analysis of your neighborhood and the traffic in the city, the digital assistant suggests that walking, cycling or car-pooling would reduce your CO2 emission account by factor -X while driving your car alone would increase your CO2 emission account by factor Y. The options and their prices (*-X or *Y) are transparent and help you make an individual decision.

Choosing specific externalities for the demonstrator to address will depend on various factors including data availability, identification of a community/city as test-bed, maturity of technology solutions, etc.

OPEN QUESTIONS IN THIS SECTION

1. How to measure in a tamper-proof way that the according action that should be rewarded or sanctioned really happened?
2. How to prevent that people game the system?

3 Architectural design

In this chapter we transform the conceptual components of the previous chapter into a technical architectural design broken down into an object view and a data (flow) view. While the design is agnostic towards specific technologies, it reveals requirements and design questions to be considered during implementation.

3.1 Object view

3.1.1 Architecture components

An initial graphical overview of (static) architectural elements is given in Illustration 3. The key elements identified so far are: Trusted data sources & Internet of Things, Cryptocurrency, Price finding mechanism & decentralized market place. The next sections provide details on each along with key questions to address in the design.

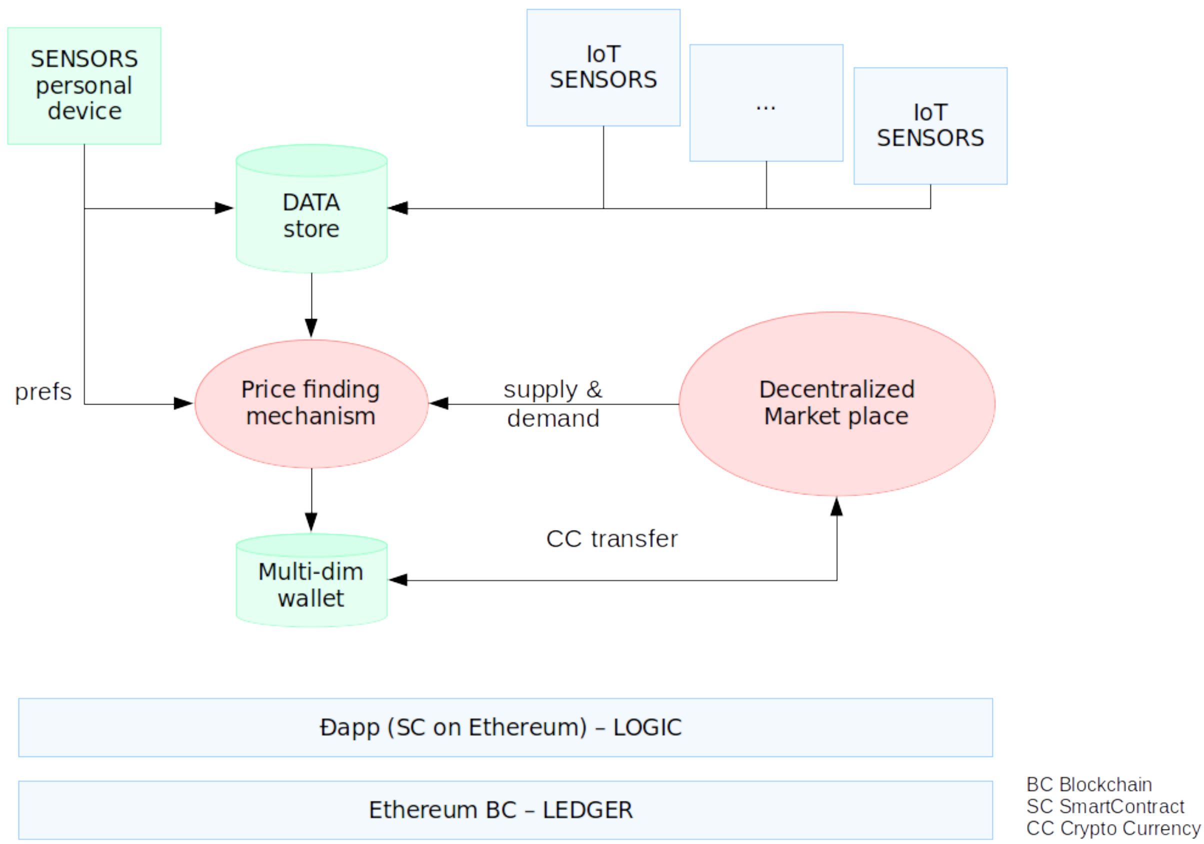

Illustration 3: Architecture Draft - Object view (own illustration)

OPEN QUESTIONS IN THIS SECTION

1. What kind of data will be stored on the blockchain? What will be stored off-chain and where? Is handling of streaming data required?
2. How can the influence of individual and collective preferences be modeled?
3. What is the most suitable conception of what the multi-dimensional wallet holds? “currency”, “securities”, “rights”, etc.?

4. Should the demonstrator be developed from scratch or should an integrative approach based on existing third party components be used? What are advantages and disadvantages?

3.1.2 Trusted data sources & Internet of Things

We can think of at least four sources where data can come from: (a) personal mobile devices, e.g. smart phones with standard sets of sensors, (b) home-grown personal devices, e.g. open hardware projects measuring weather, emission, etc. (c) [wireless] sensor networks, d) open public data, e.g. from city measurements

We investigate the following externalities to include in the demonstrator:

Positive externality	**Negative externalities**
Education	Emission
Co-operation	Pollution
Health	Disease
Community Services	Use of raw materials
Reuse / Recycling	Deforestation

There is a number of IoT data sources, we have already screened. Contacts have been established to the following networks:

- The Thing Network, https://www.thethingsnetwork.org/: "The Things Network is about enabling low power Devices to use long range (LoRaWAN) Gateways to connect to an open-source, decentralized Network to exchange data with Applications and Platforms." It is an open hardware project based on Arduino boards, offering their own SDK.
- Cahersiveen IOT Living Lab. http://iot.livinglab.ie/: "The Cahersiveen IoT living lab is an independent, state of the art 'internet of things' testbed which is located in the south west region of Ireland on the atlantic coast. Several wireless technologies have been deployed throughout the town. Including LoRa, WiFi, both ibeacon and eddystone beacons, and NFC. Creating a unique testbed with true IoT infrastructure. The IoT living lab has been built to be accessible to all academic institutions and for all company types, from SMEs to large multinationals."

Throughout the project, a comprehensive list of IoT networks as potential data sources for the Finance 4.0 concept will be assembled.

OPEN QUESTIONS IN THIS SECTION

1. What is a useful design for trusted data sources? How can trust in the sensors and sensor networks as well as the communication links into the Fin4 platform be established and secured?

As closed systems, blockchains are unable to retrieve data from the outer world by themselves. In the blockchain space, an "oracle" is a party which provides reliable and trusted data, like e.g. price feeds, weather data, random number generation, etc. Decentralized oracle systems have to cope with limitations like predefined data exchange formats and inefficiencies as all involved parties will ask for a fee and will need time to reach critical mass. Alternatively, one can demonstrate that the data fetched from the original data-source is genuine and untampered by accompanying the data with an authenticity proof: http://oraclize.it and https://tls-n.org/ propose models for this.

OPEN QUESTIONS IN THIS SECTION

1. Which data aggregation processes to use in order to preserve the informational self-determination of individuals while allowing for a capable, ideally (near) real-time, processing of data?
2. How would the accuracy and correctness of measurements be accounted for? What kind of "oracles" are needed? Who should run them?
3. Which critical mass is needed to get enough data points to do calculations? E.g., how many people would have to measure (and share) emission data (cf. http://luftdaten.info/).
4. How would trusted personal devices look like: cf. Wireless Battle Mesh (battlemesh.org), FabLabs, etc. and other open hardware communities.
5. How to find a consensus about off-chain data (cf. smart flight insurance projects)?

3.1.3 Cryptocurrency

"A cryptocurrency (cc) is a digital asset designed to work as a medium of exchange using cryptography to secure the transactions and to control the creation of additional units of the currency. Cryptocurrencies are classified as a subset of digital currencies and are also classified as a subset of alternative currencies and virtual currencies. Bitcoin is the most prominent example of a cc. To manage smaller amounts of cryptocurrency, digital wallets are used, e.g., on a smart phone. As opposed to centralized electronic money/centralized banking systems, Bitcoin and its derivatives use decentralized control, which is related to the use of a blockchain transaction database in the role of a distributed ledger."[11]

The CCs in the Fin4 system need to be easy to be emitted by everyone and at the same time allow for specific characteristics.

OPEN QUESTIONS IN THIS SECTION

1. What are the technical requirements for a blockchain, smart contract system and wallet to enable the Fin4 system?
2. Can we come up with a modular design of cryptocurrencies so communities, people and organizations have an easy-to-use building set for cryptocurrencies at hand?

3.1.4 Price finding mechanism & decentralized market place

The price finding mechanism in the Fin4 system would not only consider demands and supply, but also preferences of local communities and individuals. An analogy could be the GPS navigation system: Besides calculating the shortest and the fastest route, it could also

11 Wikipedia, Cryptocurrency.

calculate the route that minimizes CO2 emissions or that represents the nicest views during the trip, etc. In other words, preferences would not be expressed on a transaction basis but rather as a general setting.

Artificial Intelligence could support us in the form of Digital Assistants. The goal is to reduce complexity through concentration and refinement of data. Digital Assistants could calculate the need for certain kinds of positive externalities as well as try to predict price fluctuations of both positive and negative externalities.

Digital Assistants are additionally needed to support collective decision making processes through the preparation and visualization of the data basis as well as comparisons to prices in similar communities.

The decentralized marketplace for externalities would allow people to trade their coins on a real marketplace while taking into account intended frictions when trying to compensate negative externalities. Transaction participants on the marketplace will be anonymous while the amount and nature of transaction would be publicly available. This way the Fin4 system guarantees the protection of personal user data, but will allow people to monitor the behavior of the system as such.

OPEN QUESTIONS IN THIS SECTION

1. What forms of collective decision making could be used? Massive open online deliberation platforms MOODs? Alternatives?
2. How can a price-finding mechanism that considers individual preferences look like? How should the preferences be weighted? Should legal entities have a separate voice?
3. Should the Digital Assistants merely compile useful data and refine it or also advice the users about – based on individual preferences – what kind of choices they could make (cf. robo-advisors in investment banking)?

3.2 Data View

Illustration 4 shows a process-oriented view on the architecture depicting the key process steps or phases (from right to left): Sensing, Storing, Proving, Tokenizing, Pricing, and Trading.

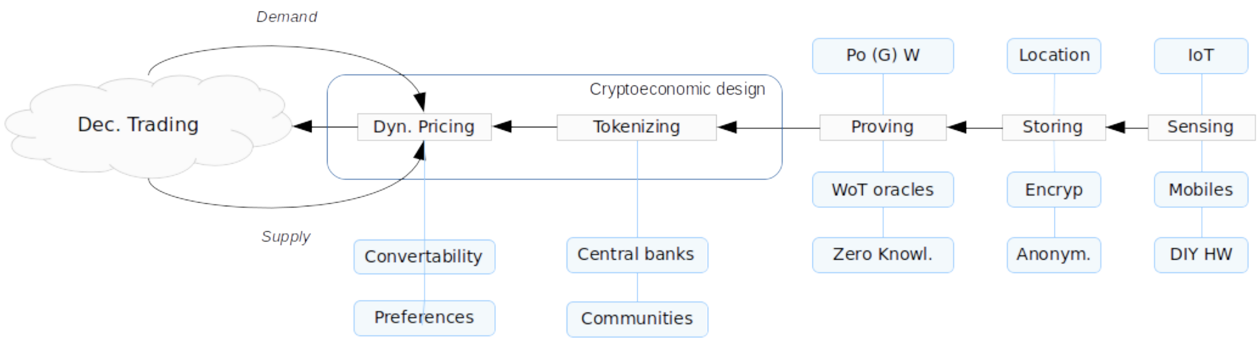

Illustration 4: High level architecture of Fin4 demonstrator (own illustration)

Sensing. The first process step ensures that the externality that is taking place in the real world gets a precise digital representation. This requires sensors to measure positive as well as negative externalities. In many cases machine sensors (IoT devices or mobile phones and other mobile devices) will be able to perform measurements and translate them in a quantitative variable. Yet, some cases will require collections of “human sensors” who are able to make judgments but who are not necessarily motivated to do so or be honest about their judgments.

Storing. Depending on the use case, data comes into the system in batches or as a continuous stream. While real-time streams may function with minimal or even none storing requirements, they pose challenges to data throughput and connectivity. Similar, data batches usually can not be real time data and require storage – either local or on the network. Any data store will have to be secured to become a trusted data vault and any connection of RT data streams need to have a secure transmission line.

Proving. Having the data transmission secured technically is not enough. Before data can be represented as a monetary value on a blockchain, the fact that the data does in fact represent the truth of what happened in the real world, some sort of oracle function needs to be in place. In the case of positive externalities one might say that a “proof of good work” is required.

Tokenizing. In this step, a numerical data value gets a representation that the network will later treat as monetary value (or equivalent) on the markets. A simple static model could assign fixed prices at this stage. More generally, the question how far the representation follows the concept of a currency or a security.

Pricing. In addition to tokenizing data sets, a separate pricing mechanism allows to define dynamic prices and let parameters such a collective and individual preferences influence the pricing – besides traditional supply and demand mechanisms.

Trading. Trading of externalities shall take place in a decentralized manner to allow anyone to participate and avoid the accumulation of control in certain parts of the network.

OPEN QUESTIONS IN THIS SECTION

1. Does the system need to accommodate batches as well as streams of data? How can the tension between anonymity and “selling”/trading of data be reconciled, particularly if a reputation score based on these balances is desired to reward users who support the network? IF a secure data storage is *not* local with the user, where is it located?

2. What types of cryptoeconomic designs are suitable to support truth-finding by collections of human sensors aka “webs of trust”? Where do the “coins” for such processes come from? How can zero knowledge proofs help here?

3. How can community-based processes for tokenization look like? What can we learn from traditional (pre-digital) concurrent currency systems? How can the system accommodate the bottom-up creation of currencies while also allow organizations like nation states and international organizations to issue currencies that are binding to larger communities?

4. When trading, how is the convertibility between currencies managed? If communities want to encourage certain currencies and discourage others, how can artificial frictions be implemented in a way that prevent misuse?

4 Technologies

The aim of developing a demonstrator is to implement key concepts described in chapter 2: pricing, trading (and measuring) externalities; multi-dimensional, multi-layered finance system, bottom-up creation of money; feedback and incentive system.

Given the fast evolving landscape of blockchain-based platforms and projects, it is worthwhile to scan the space as initiatives may come up which are conceptually or technically close to the architecture we are aiming for.

For that purpose, we are maintaining a list of interesting projects (see 4.1). As the blockchain landscape is still in its infancy, the challenge is not only to identify relevant projects and initiatives, but also to counter the lack of shared understanding of commonalities and differences between the various projects. To contribute to that development, we are developing a more general taxonomy for blockchain systems which should be useful beyond futurICT2 (see 4.2).

4.1 Ecosystem of decentralized applications (dapps)

Currently, the list of interesting projects contains 31 different platforms, projects and protocols of the blockchain or distributed ledger technologies (DLT) ecosystem (c.f. Table 1).

We sort the projects by their main function/application using a range of tags, of which a few a highlighted here.

Storage. Fin4 requires an option to store the IoT data coming from the sensors. Several projects work on solutions to provide secure blockchain-based data storage. Data domains can range from IoT to social networks and Artificial Intelligence (AI).

Trading/Marketplace. Fin4 requires possibilities to enable the trading of tokens created from the data. This is an area where many blockchain projects are working on to provide decentralized marketplaces for various kinds of data.

Governance. Fin4 foresees that communities are not only able to issue their own tokens, but also self-organize. In the blockchain space, there are several projects that support governance systems / organizations. One interesting aspect here will be to evaluate the concept of decentralized autonomous organizations (DAOs). They allow the organization of groups and follow a specific set of rules and some can even interact with other DAOs to form a network of DAOs.

Most of these platforms use smart contracts to implement their specific features. Many of them are based on Ethereum, the leading public blockchain supporting smart contracts.

At this stage, our choice for the technical blockchain platform for the demonstrator is Ethereum. Several reasons: (a) Ethereum is the most mature smart contract platform as of date, (b) the Ethereum (developer) community is the second largest after Bitcoin; (c) accordingly, the tools for and documentation about the system are actively maintained, and (d) there is an abundance of example code to investigate and learn from; (e) efforts to standardize smart contract systems are actively undertaken (e.g., ERC20, ERC223).

main tag	Name (https)	Description
AI data	**https://singularitynet.io/**	Project to monetize AI, allowing companies, organizations, and developers buy and sell AI at scale.
Blockchain-as-a-Service	**https://ardorplatform.org/**	Blockchain-as-a-Service Platform for Business
Blockchain-as-a-Service	**https://nem.io/**	Platform for application developers
community	**https://colony.io/**	Platform for open organizations.
DAO network	**https://district0x.io**	Network of decentralized markets and communities.
DAO network	**https://gospiral.net/**	Network of decentralized community currencies. Powered by EOS and IPFS
governance	**https://aragon.one**	project that aims to disintermediate the creation and maintenance of organizational structures by using blockchain technology.
governance	**https://kleros.io/**	Project uses blockchain and crowd-sourcing for evaluating complex evidence and adjudicating claims in a fast, transparent and decentralized way
Identity	**https://ambrosus.com/**	Project to implement a supply-chain ecosystem based on blockchain and IoT
inter-blockchain	**https://cosmos.network/**	Decentralized network of independent parallel blockchains, each powered by classical BFT consensus algorithms like Tendermint.
inter-blockchain	**https://polkadot.network/**	Heterogeneous multi-chain technology
internet	**https://maidsafe.net/**	Autonomous Data Network and storage solution.
IoT data	**https://iota.org/**	Platform to make every technological resource a potential service to be traded on an open market in real time.
marketplace	**https://swarm.city/**	Decentralized commerce platform
marketplace	**https://datum.org/**	Marketplace for social and IoT data
marketplace	**https://enigma.co/**	Second-layer, off-chain network that aims to solve the two problems for blockchains: scalability and privacy
marketplace	**https://www.dex.sg/**	Decentralised data marketplace
marketplace	**https://bancor.network/**	Decentralized Liquidity Network that allows you to hold any Ethereum token and convert it to any other token in the network.
prediction market	**https://gnosis.pm**	Platform for prediction markets.
prediction market	**https://augur.net/**	combines prediction markets with decentralized networks to create a accurate forecasting tool
Processing/ smart contracts	**https://www.cardanohub.org/en/home/**	Smart contract platform
social data	**https://www.reputeplatform.com/**	Infrastructure for measuring domain specific reputation
storage	**https://bigchaindb.com/**	
storage	**https://bluzelle.com/**	Decentralized database service for dApps
storage	**https://filecoin.io/**	A Decentralized Market for Storage
storage	**https://sia.tech/**	Decentralized storage platform secured by blockchain technology
storage	**https://storj.io/**	Blockchain-based object storage
storage	**https://swarm-guide.readthedocs.io/en/latest/introduction.html**	Distributed storage platform and content distribution service
trading	**https://aira.life**	Project implementing economic interaction between human-robot and robot-robot via liability smart contracts.
trading	**https://streamr.com**	Tokenizes streaming data to enable a machines & people to trade on a decentralized P2P network
trading	**https://www.swapy.network/**	Projects for efficient credit markets

Table 1: Decentralized applications identified for Fin4, sorted by main function (work in progress, author's illustration)

OPEN QUESTIONS IN THIS SECTION

1. How to cope with the very dynamic and evolving landscape of blockchain projects? How to identify a target set and then select a suitable subset to use as building blocks for the FIn4 system?
2. How to assess maturity, quality, and related aspects of these projects? How to best use the growing amount of open source code available? How to address integration and compatibility challenges?
3. How to develop a more general, systematic approach of identifying and evaluating blockchain projects? What are useful characteristics to distinguish them?

4.2 Towards a taxonomy of blockchain technologies

The whole ecosystem suffers from a general lack of shared understanding of terminology, concepts, which makes comparisons of commonalities and differences between different blockchain(-based) projects difficult and time-consuming.

To make it easier for other researchers and practitioners to efficiently identify and select projects to join, use, or integrate, we aim at developing a more generic structure to compare projects.

We start with a conceptual view of the various projects (section 4.2.1) and classify them based on this concept into a taxonomy (section 4.2.2). This work is very much in progress at the moment, so we only provide snapshots of the ongoing classification work.

4.2.1 Disentangling key terms and concepts

From classifying a few dozen projects, we identified five key properties that seem to help identify and categorize blockchain projects (c.f. Illustration 5):

- Transaction: Transactions are the type of actions, which can be logged in the distributed ledger technology.
- Consensus: Consensus is the mechanism, which allows to write transaction to DLT, adhering/ following/ observant to a set of rules.
- Distributed ledger technology: A DLT is a database of entries shared by nodes participating in a system governed by a consensus mechanism.
- Token: A Token is unit of value issued within a DLT system and which can be used as a medium of exchange or unit of account
- Underlying: An underlying gives value to a token.

OPEN QUESTIONS IN THIS SECTION

1. Which definitions are currently used in practice for concepts like token, transaction, consensus, underlaying, etc.?
2. What role does the notion of on-chain vs. off-chain actions play when defining transactions?
3. How can the topology of the physical network of nodes be integrated into the concept?

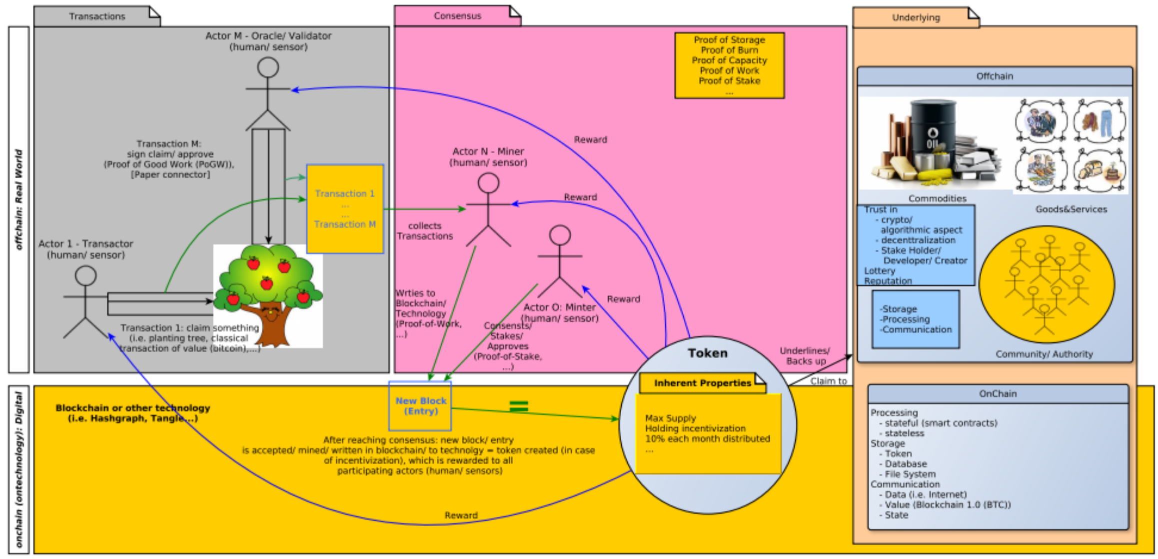

Illustration 5: Conceptual view of a typical blockchain project (author's illustration)

4.2.2 Taxonomy

Based on the conceptual view of the previous section (section 4.2.1), one can classify the different distributed ledger technologies of section 4.1. This is exemplary done for the Bitcoin project in Table 2.

Every category captures an important feature of a cryptoeconomic dimension. The *Ownership* category is utilized by all projects and specifies if the dimension is actually utilized (*yes/no*) and if the dimension is maintained and developed by the classified project (*native*) or if it is borrowed from an infrastructure project (*infrastructure*).

The DLT dimension has furthermore the type of the DLT as a category. Currently, we identified three different characteristics: Blockchain, Tangle, Hashgraph.

The categories of the consensus furthermore specify the type of consensus and who can participate in it.

The transaction dimension is also specified by the categories of who can read/ write to the DLT. Furthermore, categories specify what type of transactions can be logged in the DLT and who validates the transactions.

The token dimension is described by the inherent properties of the token, its underlying and how tokens are created.

The categories of the underlying dimension specifies which underlyings on-chain and off-chain give value to the Token.

OPEN QUESTIONS IN THIS SECTION

1. Are there major blockchain project outside the scope of futurICT2 that the taxonomy is ill-equipped to accommodate?
2. What are sources for agreed definitions for terms? Which definitions can be considered stable at this point and where are working definitions needed in order to proceed?

Cryptoeconomic dimension	definition	Category	Characteristics	Explanation	Bitcoin
Distributed Ledger Technology	*A **DLT** is an database of entries (containing recorded actions) shared by nodes participating in a system governed by a consensus mechanism. (generalization of (bitcoin wiki) blockchain def.)*	Ownership	{native, Bitcoin, Ethereum, no}	Does the project use a distributed ledger-technology and if yes, by whom is it developed/maintained (own/ infrastructure/hybrid (combination of own & infrastructure)	native
		Type	{Blockchain, Hashgraph, Tangle}	Type of the underlying distriubted ledger technology	Blockchain
Transaction	*A **trasaction** is a claim, broadcast to the network and collected into DLT entries (generalization of bitcoin transaction). **Entry**: Record at DLT containing information on occurred actions (generalization of bitcoin block). **Claim** = Behauptung/ Beanspruchung*	Ownership	{native, infrastructure, hybrid, no}	Does the project support Transactions and if yes, who is defining the type of transactions (own/ infrastrucute)	native
		wite	{public, restricted, private}	Who is able to perform a transaction/ write to DLT	public
		read	{public, restricted, private}	Wo is able to read the transactions/ from DLT	public
		Validation	{Oracle, Miner, Transactor}	Who signs/ validates claims/ transactions	Miner
		what	{Token, physical work, smart contract deployment, data storage, voting/ managing DAO}	What type of transactions can be logged in DLT	Token
Consensus	***Consensus** is the mechanism of writing entries to DLT, adhering/ following/ observant to a set of rules that all nodes will unfailingly enforce when considering the validity of a entry and its containing actions. (generalization of bitcoin consensus)*	Ownership	{native, infrastructure, no}	mechanism and if yes, who is responsible for it (project/ infrastructure) - maybe use terminology embedded consensus	native
		Who	{private, permissioned, non-permissioned}	Who is alowed to participate in the consensus: everyone (non-permissioned), some public stakeholders (permissioned) or unknown/ hidden entity (private)	non-permissioned
		Nakamoto	{yes, no}	in case of non-nakamoto: the key difference is that consensus on a block can come within one block, and does not	yes
		Type	{PoW,PoS,Hybrid-PoW-PoS, Proof-of-Authority, P-of-capacity, P-of-Storage,P-of-burn,Proof-of-space-time, Proof-of-Importance, BFT PoS }		Proof-of-Work
Token	*Token is a unit of value issued within a DLT system and which can be used as a medium of exchange or unit of account*	Ownership	{native, infrastructure, hybrid, no}	Does the project have a Token and if yes, it is native to the project or the infrastructure	native
		Creation	{Consensus, Gensis, Gensis + burn bitcoin}		Consensus
		Properties	{capped, inflation, burned fees}		capped
		Reason	{Incentivization of Consensus, ICO, payment services, governance DAO, Participation in Consensus}	The purpose of the project token	Incentivization Consensus
		Usage	{Currency, Processing, Communication,Voting, Staking}	For what is the project token used	Currency
Underlying	*An **underlying** gives value to Tokens*	onchain	{Storage, Processing, Communication, Commodity, Service, Payment, DAO, markets & communities}	What is the underlying of the Project	Payment
		offchain	{Storage, Processing, Communication, Commodity, Service, Payment}	What is the underlying of the Project	

Table 2: Draft taxonomy for DLT projects, with Bitcoin as a worked example (author's illustration)

5 Use cases

In 2015, the United Nations adopted a set of goals to end poverty, protect the planet and ensure prosperity for all – the Sustainable Development Goals (Illustration 6). FuturICT2.0 aims to utilize Finance 4.0 to contribute to these goals.

Illustration 6: Sustainable Development Goals (United Nations)

In order to so, we aim to work together with initiatives and projects in some of the 17 goal domains. Ideally, they will serve as real-world testbeds to test the various assumptions and design decisions for the demonstrator. Table 3 Shows the current list of projects observed.

Project name	Description
bitstoenergy.ch/	Joint research initiative (ETH Zurich, Univ. Bamberg, Univ. St. Gallen), combines information technology and behavioral sciences to promote sustainable energy consumption.
gospiral.net/	Support and help implementing a network of decentralized community currencies which are based on their environmental and social goals.
regen.network/	Implement an incentive-token network that rewards acts of regeneration.
Sustainability International (Niger Delta cleaning)	Sustainability International and the blockchain coalition are looking to use “smart contracts” to bypass corruption and solve the problem of distrust in Ogoniland (Nigeria) and clean up the Niger delta.
Liberland	Sovereign state located between Croatia and Serbia on the west bank of the Danube river.
Climate Drops	Project to tokenize storage/ savings of C02 through machine learning and blockchain technologies

Table 3: Overview of initiatives and projects addressing the Sustainable Development Goals

Orientation meetings have been hold with several of the projects to evaluate cooperation potential.