Blockchains & Sustainable Development

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BLOCKCHAIN FOR GOOD

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Caisse des Dépôts GROUPE

INSTITUT Louis Bachelier

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“

Whereas most technologies tend to automate workers on the periphery doing menial tasks, blockchains automate away the center. Instead of putting the taxi driver out of a job, blockchain puts Uber out of a job and lets the taxi drivers work with the customer directly”.

Vitalik Buterin, September 30, 2015

in “*Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*”, Don Tapscott, Alex Tapscott, Penguin, 10 mai 2016 - ISBN 9781101980156

ABOUT US

Blockchain for Good is a *de facto* non profit organization since 2018, registered in 2021. Its purpose is to enhance, promote, support and contribute to fundamental and applied research in digital innovations, foster and support the sharing of experiences between the blockchains ecosystem and sustainable development actors, and promote a legislative and normative framework favorable to innovation.

OUR PARTNERS

Blockchain@X is the academic chair on blockchains of École Polytechnique. It was created in 2017 with the support of Capgemini, Nomadic Labs and Caisse des Dépôts. As a multidisciplinaryresearch unit, Blockchain@X combines academic excellence with business and technology leadershipto accelerate blockchain applied innovation. Founded by Daniel Augot et Julien Prat, it brings together researchers in computer science and economics whose research focuses on blockchains and associated technologies. The unit has three specific mandates : academic research, teaching and Though-leadership.

Caisse des Dépôts and its subsidiaries constitute a public group, a long-term investor at the service of the general interest and the economic development of the territories. It has five areas of expertise: social policies (retirement, vocational training, disability, senior citizens, and health), asset management, monitoring of subsidiaries and shareholdings, corporate financing (with Bpifrance) and Banque des Territoires.

The **Institute Louis Bachelier** (ILB) is a non-profit organization created in 2008. Its activities aim to engage academic researchers, as well as public authorities and private companies in research projects in economics and finance with a focus on four societal transitions: environmental, digital, demographic and financial. The ILB is, thus, fully involved in the design of research programmes and initiatives aimed at promoting sustainable development in economics and finance. In 2021, the ILB hosted more than 70 research programmes.

Bpifrance is supporting companies at every stage of their development with loans, guarantees and equity capital. Bpifrance supports them in their innovation and international projects. Bpifrance also ensures their export activity through a wide range of products. It also offers advice, universities, networking and acceleration programs for startups, SMEs and ETIs.

PositiveBlockchain.io is all at once an open database, a media outlet, and a community that explores the potential of blockchain technologies for social and environmental impact. They like to call themselves “Blockchain Positivists”.

The **ELYX Foundation**, under the aegis of the Bullukian Foundation, is recognized as a public utility. Its programs aim to make the 2030 Agenda a success, to participate in an ambitious and inclusive culture, and to promote innovation as a lever for 2030.

The Blockchain for Good Association publishes independent analyses and the opinions expressed in this report are the sole responsibility of the authors and not of the individuals or organizations consulted, nor of our partners, the Insitut Louis Bachelier, the Blockchain@X chair at École Polytechnique, the Caisse des dépôts, Bpi France, PositiveBlockchain.io, and the Elyx Foundation.

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AUTHORS

Jacques-André Fines Schlumberger. Doctor in information and communication sciences, with a Master's degree in political science and a Master's degree in business law, Jacques-André Fines Schlumberger has been an entrepreneur since 2000, working on social and digital innovations. He is a lecturer at the University Panthéon-Assas (Paris 2) and author for *La revue européenne des médias et du numérique*. He has been studying blockchains and their practical applications for a long time, and under the prism of sustainable development since 2018.

Pierre Noro. After several years building blockchain-based public services with France's main public finance institution, Pierre Noro now works with innovative companies to design and develop impact-oriented blockchain projects. He is a researcher and a lecturer at Sciences Po Paris and at the Learning Planet Institute (Université Paris-Cité). In addition to his work on decentralized governance and digital ethics, he is part of the team developing Pebble.vote, the first decentralized, transparent and secure e-voting solution.

Lucas Zaehringer. Co-founder of Positiveblockchain.io, Lucas Zaehringer has been exploring the interlinks between blockchain and social impact since 2017. He is also Lead Europe at Verity Tracking, a start-up leveraging blockchain and tokenization to decarbonize bio-based value chains such as biofuels or agricultural commodities.

CONTRIBUTORS

Louis Bertucci, Research Fellow at Institut Louis Bachelier.
Pierre Champsavoir, Expert in risk management and sustainable finance.
Noémie Dié, PhD student in economics at Télécom Paris and Bpifrance Le Lab.
Alejandro Gómez, **Christophe Gbossou**, Expert members, Africa 21.
Audran Gouis, Student at Sciences Po Paris, School of Public Affairs.
Ani Ramos, Co-founder of Positiveblockchain.io, Product Manager @Palm NFT Studio.
Razali Samsudin, Independent researcher, Educator, Co-founder of Sustainable ADA.

REVIEWERS

(Legend : I = introduction ; Chapter = 1 to 12 ; C = conclusion - The links go to the Linkedin social network)

Géraud Ahouandjinou (10), Hervé Alexandre (2), Daniel Augot (1), Louis Bertucci (I, 4, 8, 11), Pierre Champsavoir (I, 1, 2), Martin Chazelle (1, 2, 10), Noémie Dié (I, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12), Christophe Gbossou (1, 2, 3, 10, 12), Patrice Geoffron (4), Alejandro Gómez (1, 2, 3, 6, 7, 10, 12), Audran Gouis (I, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12), Thibaud Huriez (1, 2, 5), Pascal Lafourcade (3), Thibault Langlois-Berthelot (1), Mathieu Lesueur (5), Paul Pflimlin (1, 2, 5), Ani Ramos (7), Paul Rivière (1, 2, 10), Stéphane Voisin (4), Lucas Zaehringer (I).

EXECUTIVE SUMMARY

This report is a continuation of the work of the Blockchain for Good association, in particular following on from the publication of a first report published in June 2020.

Both reports attempt to answer the question of whether and **how blockchains could help accelerate the achievement of the Sustainable Development Goals** in a meaningful and sustainable way.

Which blockchains, which Sustainable Development Goals? For what purpose and how? Which decentralized projects work? In which areas and according to what governance? Is it possible to reconcile certain blockchains and the energy consumption required for their operation with the Sustainable Development Goals? Why are so many experts at the United Nations convinced that blockchains will play an important role in sustainable development and will contribute to the preservation of the environment? Why is it that international and non-governmental organizations have been experimenting with the implementation of blockchain projects since 2013, in fields as varied as supply chain, payment, money transfer, crypto-assets, livestock traceability, digital identity and even land registration?

The diversity of use cases for “blockchain for good” projects seems to result from natural convergence of the principles of transparency, traceability, collaboration and decentralization that underlie these distributed registers and which are implicit in the Sustainable Development Goals.

Can the global health crisis, triggered by the Covid-19 pandemic and the awareness of the value and resilience of decentralized models serve as an accelerator for the use of this class of technology? Nothing is less certain.

After recalling the fundamentals of the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals, defined in the context of the framework of discussions between the 193 member states of the the United Nations and civil society, we look at how blockchains work and their added value, distinguishing between public and private.

What is the contribution of public blockchains in terms of decentralization and governance? What are smart contracts*, decentralized applications (dApps*) and decentralized autonomous organizations organizations (DAOs*)? What about the energy consumption of Bitcoin?

Today, blockchains serve four main purposes:
1. **peer-to-peer exchange of owned digital assets**,
2. **moving to the decentralized digital identity paradigm**,
3. **keeping an unforgeable record of data**, and
4. **programming digital assets**, each of which can be combined with any other.

The second edition of this report "Blockchains & Sustainable Development" has been an opportunity to collect information about some 700 blockchain projects - each of which is related to the pursuit of one or more of the Sustainable Development Goals.

An online directory, created by PositiveBlockchain.io in 2018 and to which the association Blockchain for Good actively contributes, is freely accessible in open data format (page 46).

These projects are divided, depending on the number of projects identified, into twelve categories:
1. Identity & Property,
2. Peer-to-Peer Electronic Cash System & Programmable Money,
3. Health,
4. Supply Chain & Logistics,
5. Energy,
6. Aid, Charity & Philanthropy,
7. Agriculture & Food,
8. Web 3.0, Art & Sciences,
9. Environment & Climate,
10. Government & Democracy,
11. Electronic Communication & Telecommunications,
12. Education & Employment.

The first finding, unchanged since our first report was written in 2020, is the extent to which there is a significant gap between the ambition, supported by a wide range of initiatives and actors, and the reality of the implementation of these projects, which still come up against many limitations, now more political than technical.

Because of their innovative nature, blockchains are disturbing.

One theme appears to traverse all activity sectors: that of **decentralized digital identity** (chapter 1).

This is a new paradigm, still developing, which holds the promise of the reappropriation by everyone of their personal data. In the model of decentralized identity, issuers deliver verifiable credentials* to individuals, - holders, who then present them to verifiers, in contrast to the centralized identity model in which a person disseminates their personal data to all the third parties with whom they interact.

With the world's population at 7.9 billion people, one billion people cannot prove their identity, despite this being crucial, according to the World Bank, for at least ten of the Sustainable Development Goals.

The large-scale adoption of centralized identity systems is currently facing resistance from the major web and private actors whose model is based on the identification of their users, notably for advertising and commercial purposes.

Decentralized digital identity also seems to be the keystone of blockchain projects in the **healthcare field** (chapter 3), aimed at protecting patient data, or in the field of **education** (chapter 12), thanks to the **certification of diplomas and educational qualifications**.

It is also the strategy of Europe, through the European Blockchain Services Infrastructure (EBSI), to promote this new paradigm of decentralized identity. Finally, the countries that are most inclined to switch to a decentralized identity system today seem to be those that are unable to provide identity to their citizens.

Gravity in Kenya, **FlexID** in Zimbabwe, and **Atala Prism** in Ethiopia are just a few of the initiatives that are implementing, on a large or small scale, this new paradigm of decentralized identity.

As for the implementation of a decentralized land registry, projects that are more or less advanced are taking shape in Ghana, Bangladesh, India, Sweden and Georgia.

While the fundamental innovation of blockchains, first and foremost Bitcoin, is the ability to transfer value on a peer-to-peer basis, without passing through an intermediary, it is clear that, once again, **the adoption of crypto-assets by the general public is much more advanced in countries marked by financial instability and those with fragile institutions** (Chapter 2).

Whether it is to send funds across borders or to protect themselves from inflation, peer-to-peer money transfers are increasingly used in some countries, including Kenya, Nigeria, Vietnam and Venezuela.

Instantaneous transfers, almost free of charge and without any nationality requirements are changing the face of money transfers.

Contrary to popular belief, blockchains and the fight against climate change are not an oxymoron.

Blockchain initiatives in environment and climate (Chapter 4) are enabling new organizations that aim to decentralize voluntary carbon markets, water markets, the financing of waste collection, donations in crypto-assets for environmental projects and even agro-ecology and reforestation projects.

By virtue of their intrinsic properties - being peer-to-peer networks and ensuring the transparency of common registries in secure environments - blockchains find in the energy sector (Chapter 8) a vast field of exploration, whether in the fields of **energy trading, energy certification or even network optimization**.

What is the impact of blockchains, smart contracts and even decentralized autonomous organizations (DAOs*) in **public services, government and democracy** (chapter 9), education and employment (chapter 12) and health (chapter 3)? *“How”*, asks Pierre Noro in chapter 9, *“can a technology resolutely anarchist, libertarian, in a sense ‘anti-state’ now be presented as an opportunity for the renovation of our democratic systems and of the public administrations, at the local, national and international levels?”*.

The promise of blockchains in the fields of **agriculture and food** (chapter 6) and **supply chain** (Chapter 5) also suggests the potential of distributed registries for traceability, information sharing and accountability of actors in complex value chains.

Our approach, by sector of activity, has allowed us to identify the main principles and the articulation of an ecosystem of peer-to-peer electronic currencies and crypto-assets linking different blockchain protocols to the pursuit of the Sustainable Development Goals.

Certainly, the challenges remain innumerable, but the analysis of numerous projects, some of which have already gone beyond the simple proof-of-concept stage, validates the relevance and effectiveness of models based on a technical architecture that distributes trust among its users, according to predefined rules, and a governance without head or center, auguring new forms of social interaction for the benefit of all.

TABLE OF CONTENTS

INTRODUCTION

Sustainable development through the lens of blockchains

There are several types of blockchains, including, to put it in a nutshell, public blockchains and private blockchains and there are intrinsically different.

The first public blockchain is called Bitcoin and was conceptualized between 2007 and 2008, then implemented in January 2009 by a person or a group of persons answering to the name of Satoshi Nakamoto, missing since December 2010. **Another notable public blockchain is called Ethereum** and was created in July 2015. Since then, nearly 20,000 public blockchains, most of which probably have no use, have been created and are listed on the coinmarketcap.com information site.

A public or common blockchain is a decentralized and secure digital ledger in which anyone can participate: reading, writing, performing transactions, verifying, and securing them, all without a central intermediary. As for private blockchains, for the company or group of actors that has control and governance it is essentially a matter of optimizing processes, sometimes already existing, often organized hierarchically in silos, and whose main concern is optimizing the registry, in order to resolve the inefficiency of information flow in such pyramidal organizations.

When we talk about blockchains in referring to Bitcoin or Ethereum and their derivatives, we are talking about public or common blockchains, which are based on the combination of several technologies, some of which were pre-existing: peer-to-peer network protocols, cryptographic techniques and, as a fundamental innovation brought by Bitcoin, the consensus mechanism through proof of work.

The skilful combination of these three technologies results in a distributed ledger, a chain of blocks of transactions linked together from the very first block, and which is called a blockchain in everyday language. However, as Alexander Stachtchenko, president of the french Association for the Development of Digital Assets (ADAN) explains, *"the major innovation of Bitcoin is the consensus without intermediaries in a computer network that allows the management and transfer of value online*[1]".

This consensus without intermediaries, which is specific to public blockchains, makes it possible to operate a peer-to-peer electronic cash system, open to all, without prior authorization or censorship. Anyone is free to use a service operated on a public blockchain, which in the case of Bitcoin is used, peer-to-peer, to receive, hold, and send electronic cash,

1 "Manuel de survie dans la jungle des poncifs anti-Bitcoin", Alexandre Stachtchenko, 21millions.capital.fr, January 5, 2022.

bitcoins, anywhere in the world. Yorick de Mombynes, a consultant at the French Court of Auditors, says that *"Bitcoin is an acephalous, decentralized, open system. No one has any power over it. It has no leader or manager. It belongs to everyone and to no one. These characteristics form an exceptionally innovative whole, the antithesis of systems based on hierarchy, (...), legal monopoly and centralism*[2]*".*

While the diversity of uses is limited only by the imagination of their designers, blockchains today serve four main types of use:

1. Exchanging peer-to-peer digital assets,

2. Using decentralized identity, even anonymously,

3. Keeping an unforgeable register of data, and

4. Programming digital assets, each of which can be combined with the others.

Exchanging digital assets peer-to-peer means exchanging digital money directly, similar to cash. While some see Bitcoin and stablecoins* as having no use, others see them as a great tool for monetary empowerment, especially for the tens of millions of people living under authoritarian regimes or unstable economies.

This is notably the case of the twenty-one human rights defenders from some twenty countries around the world who recently wrote a letter to the U.S. Congress, for whom "*Dollar and euro users have most likely not experienced extreme currency devaluation or the cold grip of dictatorship. To most in the West, the horrors of monetary colonialism, misogynist financial policy, frozen bank accounts, exploitative remittance companies, and an inability to connect to the global economy might be distant ideas. To most of us and our communities — and to the majority of people worldwide — they are daily realities. If there were "far better solutions already in use" to overcome these challenges, we would know*[3]".

2 "Bitcoin : la monnaie ouverte et ses ennemis", Yorick de Mombynes, January 18, 2022, https://www.latribune.fr/opinions/tribunes/bitcoin-la-monnaie-ouverte-et-ses-ennemis-902225.html
3 "Letter in Support of Responsible Crypto Policy", Washington, DC 20510, June 1, 2022, https://www.financialinclusion.tech

Country	Index score	Overall index ranking	Ranking for individual weighted metrics feeding into Global Crypto Adoption Index		
			On-chain value received	On-chain retail value received	P2P exchange trade volume
Vietnam	1.00	1	4	2	3
India	0.37	2	2	3	72
Pakistan	0.36	3	11	12	8
Ukraine	0.29	4	6	5	40
Kenya	0.28	5	41	28	1
Nigeria	0.26	6	15	10	18
Venezuela	0.25	7	29	22	6
United States	0.22	8	3	4	109
Togo	0.19	9	47	42	2
Argentina	0.19	10	14	17	33
Colombia	0.19	11	27	23	12
Thailand	0.17	12	7	11	76
China	0.16	13	1	1	155
Brazil	0.16	14	5	7	113
Philippines	0.16	15	10	9	80
South Africa	0.14	16	18	16	62
Ghana	0.14	17	32	37	10
Russian Federation	0.14	18	8	6	122
Tanzania	0.13	19	60	45	4
Afghanistan	0.13	20	53	38	7

The 2021 ranking of the global crypto-currency adoption index

Source: "The 2021 Geography of Cryptocurrency Report", Analysis of Geographic Trends in Cryptocurrency Adoption and Usage, Chainanalysis, Oct 2021, https://go.chainalysis.com/rs/503-FAP-074/images/Geography-of-Cryptocurrency-2021.pdf.

Sending and receiving money without intermediaries, at virtually no cost, and with no geographical constraints. Protecting yourself from currency devaluation. Trading with foreign countries, without banking restrictions. According to the Global CryptoCurrency Adoption Index 2021, published by Chainanalysis, the highest rate of adoption of crypto-currencies is among those who do not have access to banks or whose banks impose restrictions, such as in Nigeria, for example, which prohibits its citizens from making foreign transfers of more than $500. As a result, "*many emerging markets are facing significant currency devaluation, driving residents to buy crypto-currencies on P2P platforms to preserve their savings*"[4], states The 2021 Geography of Cryptocurrency Report, also published by Chainanalysis" poursuit le rapport *The 2021 Geography of Cryptocurrency Report*[5] publié par Chainanalysis.

4 "The 2021 Global Crypto Adoption Index: Worldwide Adoption Jumps Over 880% With P2P Platforms Driving Cryptocurrency Usage in Emerging Markets", Chainanalysis, October 14, 2021, https://blog.chainalysis.com/reports/2021-global-crypto-adoption-index/

5 "The 2021 Geography of Cryptocurrency Report", Analysis of Geographic Trends in Cryptocurrency Adoption and Usage, Chainanalysis, October 2021, https://go.chainalysis.com/rs/503-FAP-074/images/

Using a stablecoin*, a crypto-asset with fixed parity to a fiat currency such as the dollar, allows people to convert their salary or savings into a more stable currency, and thus protect themselves against the devaluation of their own currency.

This is a daily reality for people in countries such as Nigeria, Turkey, Lebanon or Argentina, whose currencies are collapsing. Some stablecoins, such as the one offered by **Agrotoken** in Argentina, are even backed by real assets such as tons of soybeans, so as to protect farmers against inflation.
(See Chapter "Peer-to-peer electronic cash system and programmable money").

Using decentralized identity, even anonymously, is to be able to benefit from an identity system that respects privacy, and above all to resolve the contradiction in that certain countries, characterized by a failure of the institutions, are unable to provide their citizens with a means of proving their identity, while in developed countries, individuals benefit from a very relative anonymity, whether for commercial and financial reasons, or for political and security reasons.

With the world's population at 7.9 billion, one billion people cannot prove their identity[6], even though this is crucial for at least ten of the Sustainable Development Goals according to the World Bank[7].

The contribution of blockchains in the field of digital identity is to move from a centralized model where the user creates a login/password and disseminates his personal information to each service he interacts with, to a decentralized model, where the user remains in control of his personal data (See Chapter "Identity and ownership").

Keeping an unforgeable data register is an opportunity to rethink the centralized character of any official register, whether it is a land register on a national scale, a land ownership register, a diploma register, or the register of a chain of traceability involving a multitude of actors whose interactions thus become more or less transparent.

Geography-of-Cryptocurrency-2021.pdf
6 According to the World Economic Forum, the latest data shows that there are just over 987 million people in the world without a legal identity, compared to 1.5 billion in 2016. The majority of them live in low-income countries where nearly 45 percent of women and 28 percent of men lack legal identity. " A billion people have no legal identity - but a new app plans to change that ", World Economic Forum, November 20, 2020, https://www.weforum.org/agenda/2020/11/legal-identity-id-app-aid-tech/
7 "ID4D. Country Diagnostic : Kenya", World Bank, 2016, retrieved May 9 2022, https://documents1.worldbank.org/curated/en/575001469771718036/pdf/Kenya-ID4D-Diagnostic-WebV42018.pdf.

Programming digital assets means implementing computerized contracts that are unstoppable, incensurable and distributed across all the nodes of a public blockchain, known as "smart contracts*". Ethereum describes itself as *a technology for building apps and organizations, holding assets, transacting and communicating without being controlled by a central authority* (ethereum.org).

They allow for more complex transactions, for example, if a product is delivered, then payment is automatically triggered. If it snows for ten days, a parametric insurance contract automatically sends an indemnity to the farmers who subscribed to it. Locally produced renewable energy can be tracked with a token and sold peer-to-peer via a standalone contract.

The smart contract allows the execution of previously established clauses in an automatic way: if the product is not delivered, the payment does not take place and as soon as the product is delivered, the payment takes place automatically. If a farmer is insured against storms and the weather event occurs, the payment of his insurance is automatic, as is the way to establish, in a decentralized way, that the weather event has occurred. When a person participates in a collective energy scheme, he automatically sells the surplus electricity he produces or automatically buys what he needs.

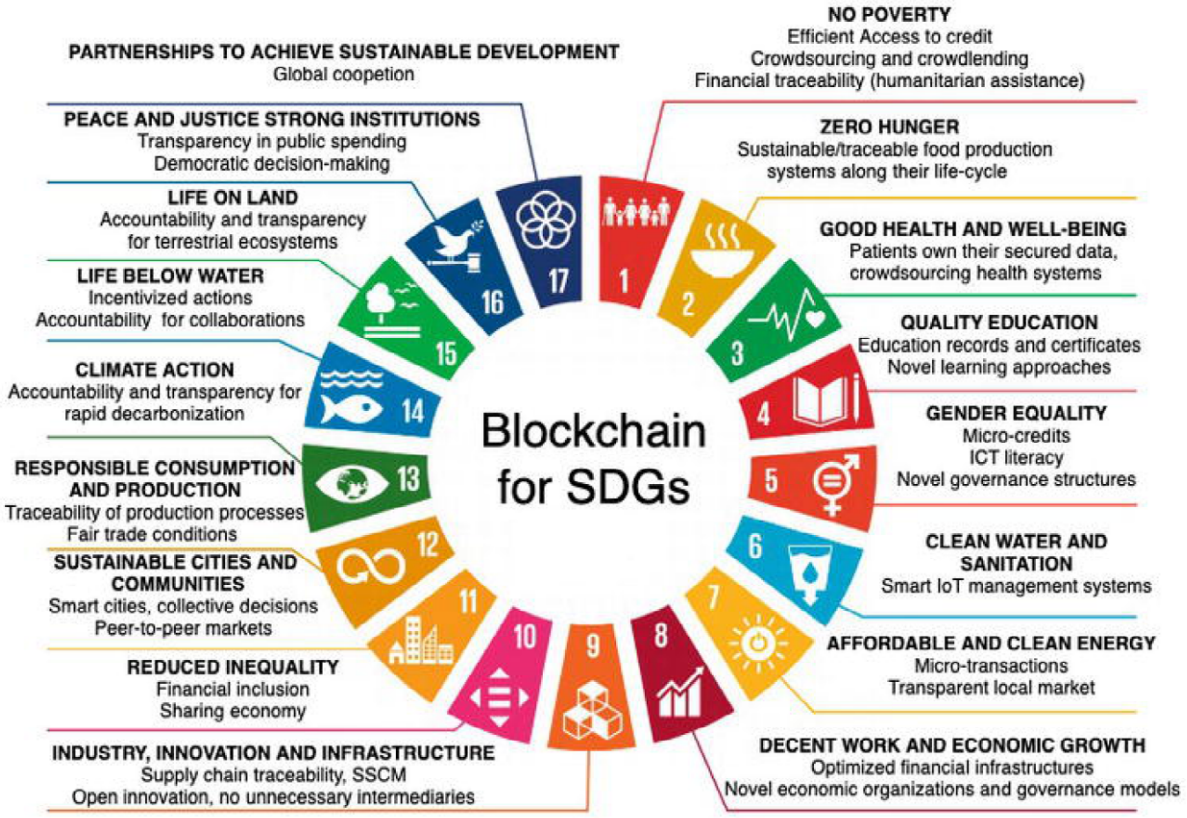
Because there is no central body, permissionless public blockchains are said to distribute trust across a network, or to be a "consensus technology".[8]

They allow users to carry out transactions of varying complexity and to trust each other without knowing each other. These technologies, charged with political ideology, are inspirational for many. "*The New Edge, extension of the New Age of the 1970s, opposes the old world, centralized, coercive and hierarchical, to a new world, decentralized, self-organized and horizontal, enshrined in an evolutionary dynamic (but by technical means and not 'occult')*" [9] explains David Pucheu, researcher at the University Bordeaux Montaigne, during the conference "Blockchain, religious imaginary and theology" organized at the Collège des Bernardins on 17 March 2021.

Just as a technical tool depends on the use that is made of it, blockchains can be used for better or worse: for the emergence of an alternative and universal monetary system, or for the implementation of the eYuan[10] (the eCNY), an unbelievable instrument of monetary surveillance developed by Beijing.

In less than fifteen years, countless so-called blockchain projects have been launched, tested, and experimented

8 "Le Rapport de l'Office Parlementaire", Jacques Favier, La Voie du Bitcoin, August 16, 2018, http://blog.lavoiedubitcoin.info/post/Office-Parlementaire
9 "Blockchain, imaginaires religieux et théologie - 2020/2021", Collège des Bernardins, March 17, 2021, https://www.collegedesbernardins.fr/recherche/blockchain-imaginaires-religieux-et-theologie-20202021
10 "La Chine accélère le déploiement de son yuan numérique", Claude Fouquet, January 5, 2022, https://www.lesechos.fr/finance-marches/marches-financiers/la-chine-accelere-le-deploiement-de-son-yuan-



Source : " Leveraging Blockchain for Sustainability and Open Innovation : a Cyber-Resilient Approach toward EU Green Deal and UN Sustainable Development Goals ", Paula Fraga-Lamas, Tiago M. Fernandez Carames, intechopen, May 7 2020, https://www.intechopen.com/chapters/72069

with by organizations of all types and in extremely varied fields.

As the technology continues to improve, as it attracts more and more developers and users, and as the first innovations become mature, many observers find the time has come to question the technology's societal utility and to identify the areas in which it brings added value to those who use it, to society and to the common goals of the international community.

Blockchain for good

Since 2013, blockchain projects stamped "for good" have been launched by non-profit associations such as **BitGive**, or developed within non-governmental organizations and international organizations whose missions are by nature aligned with the Sustainable Development Goals (SDGs).

In 2015, UNICEF conducted a first experiment on the Bitcoin blockchain to test an "immutable identity system" and explained that "*if we could take a person's*

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photo, link it to their personal information (date of birth, name, etc.), encode these elements and publish a cryptographically secure link to the encoded information on the blockchain, this link, because it would be on a public network and without permissions, would last 'forever' and constitute an immutable identity".

In 2016, UNICEF set up a venture capital fund to support young technology companies in emerging markets.[11]

As of November 2018, this fund had 72 investments in data science and artificial intelligence, blockchain and Mixed reality, including 33 in startups based in countries where UNICEF is active[12].

A dozen other UN agencies have initiated, as of 2017, a number of blockchain projects conducted individually or collectively, in areas as varied as supply chain, payment and money transfer in digital currency, livestock tracking, digital identity or land registration.

A report by the United Nations Joint Inspection Unit calls these initiatives, in 2020, "*unprecedented opportunities for inter-agency collaboration*", while acknowledging the amount of work necessary to implement an encompassing roadmap. For Thomas Davin, Director of the Office of Innovation at UNICEF, "*we have seen no other technological development with as much growth in recent years - or more potential to solve every conceivable problem - as Bitcoin, Ethereum and other applications of blockchain technology*".[13]

Yet, "*few countries are showing support for the adoption of blockchains and crypto-currencies in their systems*",[14] says Okonjo Iweala, director general of the World Trade Organization (WTO), probably because it would make processes transparent that current recipients prefer to keep opaque. While blockchain initiatives could be used to "*reduce poverty, empower women and give them easy access to financial markets*", adds Okonjo Iweala, the problem is, at the moment, "*we are still far from realizing this vision*".[15]

11 "UNICEF Is Investing In Tech Startups", Michael Astor, UNICEF, November 15, 2016, https://www.unicef.org/innovation/stories/unicef-investing-tech-startups
12 "Programme UNICEF Venture Fund", UNICEF, retrieved June 15, 2022, https://www.unicef.org/innovation/venturefund
13 "Blockchain applications in the United Nations system: towards a state of readiness", Petru Dumitriu, Report of the Joint Inspection Unit, July, 2020, https://www.unjiu.org/sites/www.unjiu.org/files/jiu_rep_2020_7_english.pdf
14 "Blockchain can be particularly beneficial to women, says WTO Director General", Luc Jose Adjinacou, CoinTribune, July 13, 2021, https://www.cointribune.com/en/analysis/people/blockchain-can-be-particularly-beneficial-to-women-says-wto-director-general/
15 *Ibid.*

PURPOSE OF THIS REPORT

Our initial questions, posed in the report we published in June 2020,[16] remain unchanged:"*How do initiatives based on blockchains, whether public or private, contribute to achieving the Sustainable Development Goals? Which blockchains, which Sustainable Development Goals? For what purpose and how? Which decentralized projects work? In what areas and according to what governance?*".

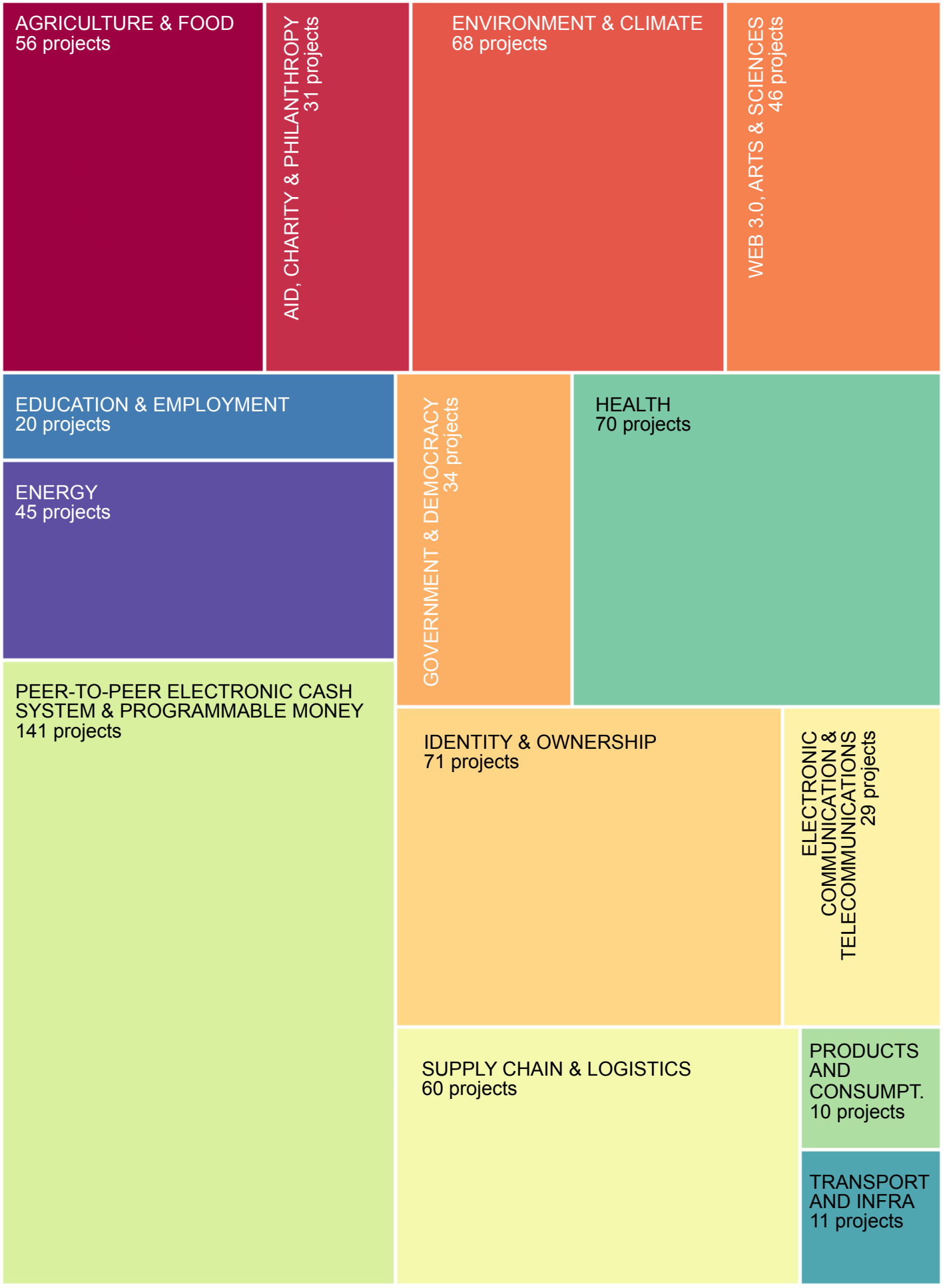
The difficulties in answering these questions are as much due to the immaturity of many blockchain projects as to the transversality of the Sustainable Development Goals, which are all closely linked, "*the success of one goal often depending on the resolution of issues generally associated with another goal*".[17]

Since it is impossible to generalize about a class of technologies as vast as blockchains, and especially because blockchains are anything but an end in themselves, we have endeavored to identify and analyze a certain number of blockchain projects and initiatives whose activities are in line with the pursuit of one or more Sustainable Development Goals.

This report is based on extensive data collection work, carried out separately since 2018 by the Positive Blockchain association and the Blockchain for Good association, and then jointly since the beginning of 2021. Available in open data, this directory of 1273 blockchain initiatives, 692 of which are active in June 2022, is the material from which this report is drawn. These projects and initiatives break down as follows:

16 "Blockchain et développement durable", Livre blanc, Blockchain X, Institut Louis Bachelier, Coreum, June 2020.
17 " Les 17 Objectifs de Développement durable à l'horizon 2030 ", Anne Chemin-Roberty, Institut Michel Serres, http://institutmichelserres.ens-lyon.fr/, September 18, 2017.

Blockchain for good Directory - Extract from open database PositiveBlockchain.io



METHODOLOGY

The directory

The French associations *Blockchain for Good* and *PositiveBlockchain.io* each conducted an initial data collection in 2018. The aim was to reference blockchain projects that relate to the pursuit of one or more Sustainable Development Goals.

In 2020, the two associations joined forces to create the "*open-database of blockchain for good projects*" accessible on positiveblockchain.io.

A major update was carried out from February to June 2022 by Lucas Zaehringer, Ronald Steyer, Flavio Santalucia and Susanne Köhler and the entire **PositiveBlockchain** team, Carlotta Cochis, Pr. Paula Ungureanu and the entire research and assistants team of **the University of Modena**, Taira Ishikura and Serena Tan of the **Ethereum Foundation**, Pierre Champsavoir and Jacques-André Fines Schlumberger of **Blockchain for Good**, Junie Maffock of **Blockchain for Africa**, Chinedu Onyeaso and Benjamin Onuoha of the **Africa Blockchain Alliance**, Peter Johnson of Ayadee Foundation, Daniel Kimotho of **Clabs**, Roxana Dumitrescu, Master student, and external contributions from the **Africa Blockchain Alliance & consortium partners** and the **Unicef Innovation Fund**.

This information gathering work, carried out throughout the year by a large network of contributors, allows us to update the data in the directory twice a year. In addition, once a year, all the active projects in the directory are reviewed one by one in order to identify the projects that have ceased their activity and those that continue.

This directory is not exhaustive, but it aims to be comprehensive enough to give an overview of the trends at work in the field of blockchains and sustainable development.

What are the sectors of activity?

The blockchain projects and initiatives identified by the network of contributors are classified in the directory by business sector, which we have divided into fourteen key categories and 68 subcategories, and whose titles and hierarchies were discussed online in March 2021 and May 2021 on two collaborative documents opened for discussion with PositiveBlockchain.io and blockchainforgood.fr. All projects are referenced in the following 14 categories:

- Agriculture and Food
- Aid and Philanthropy
- Climate and Environment
- Digital Content and Arts
- Education and Employment
- Energy
- Finance and Insurance
- Government and Democracy
- Health
- Identity and Ownership
- Internet and Telecommunications

- Logistics and Traceability
- Products and Consumption
- Transportation and Infrastructure

Our approach has been to make the online directory easy to use, so that it can be understood, explored and easily appropriated by a wide audience.

Correlation of the sectors of activity with the Sustainable Development Goals

To correlate the categories and subcategories of the directory with the Sustainable Development Goals (SDGs), we relied on the Toniic SDG Impact Theme Framework.[18]

The objective of the Toniic SDG Impact Theme Framework is "*to enable impact investors to align their investments with the SDGs and thus find greater alignment and synergy in global investment opportunities*".[19]

Writing the report

For the purposes of writing the report, we converted each of the directory's categories into chapters within which we provided an overview of the services deployed by browsing the projects referenced in the directory and drawing on the journalistic and scientific literature listed in the footnotes.

Due to a lack of information, the categories "Transport and Infrastructure" and "Products and Consumption" are not covered in a specific chapter and some of the projects identified are cited in the other chapters.

This report is divided into twelve chapters: Identity & Ownership; Peer-To-Peer Electronic Cash System & Programmable Money; Health, Environment & Climate; Supply Chain & Logistics; Agriculture & Food; Web 3.0, Arts & Sciences; Energy; Government & Democracy; Aid, Charity & Philanthropy; Electronic Communication & Telecommunications; Education & Employment.

Each chapter aims to provide an overview of the sector, an understanding of the promise of the blockchain initiatives identified, including how they work, and the identification of exemplary projects, particularly in terms of their governance and their innovative nature.

We have organized the chapters according to the number of projects referenced in the directory, except for the first chapter, "Identity and Ownership" which we believe is a fundamental theme whose contemporary issues both transcend and feed into the other themes addressed in this report.

18 "Toniic SDG Impact Theme Framework", Toniic, September 18, 2019, https://toniic.com/sdg-framework/
19 *Ibid.*

Each chapter of this report has its digital double, in the form of a Google Docs link.

Thus, if you wish to exchange, discuss or amend the report, you are invited to do so directly online in order to feed the reflection and the debates on these subjects.

All words marked with an asterisk (*) are defined in the glossary at the end of the report.

Limits

The data and updates in the directory are the result of an extensive process of information collection that relies on a network of international contributors. The diversity of projects and the speed with which some projects are created and others disappear make it impossible to keep a directory permanently up to date, and some projects will no longer be active or will have evolved by the time this report is published. Please consider this an invitation to join us as a contributor to the directory.

The Blockchain for Good association publishes independent analyses and the opinions expressed in this report are the sole responsibility of the authors and not of the individuals or organizations consulted, nor of our partners, the "Blockchain & Platform" Chair at Ecole Polytechnique, created with the support of Capgemini, NomadicLabs and the Caisse des Dépôts et Consignations; the Banque Publique d'Investissement (Bpifrance); and the Caisse des Dépôts Group.

SUSTAINABLE DEVELOPMENT GOALS

IMPACT THEME FRAMEWORK V1.1

	U.N. PRIMARY SDG	TONIIC IMPACT THEME	U.N. ADDITIONAL SDGs
	End poverty in all its forms everywhere	Access to basic goods and services (p.4)	8
		Financial inclusion (p.4)	9, 17
		[Affordable housing - See SDG 11]	
		[Small holder farmers - see SDG 2]	
	End hunger, improve nutrition, and promote sustainable agriculture	Food security (p.4)	3, 4
		Food waste (p.4)	12
		Healthy food (p.4)	3
		Small holder farmers (p.5)	1
		Sustainable agriculture (p.5)	15
	Ensure healthy lives and promote well-being for all at all ages	Access to healthcare (p.5)	1
		Ageing (p.5)	10
		Maternal and reproductive health (p.6)	5
		Mental health (p.6)	
		Disease prevention and response (p.6)	
		Fitness and wellbeing (p.6)	
		Biotechnology (p.6)	
	Ensure quality education for all	Access to education (p.7)	1, 5
		Education systems (p.7)	16
		Upskilling (p.7)	8
	Achieve gender equality and empower all women and girls	Products and services for women (p.8)	
		Women inclusive corporate policies (p.8)	10
		Women leadership and capital (p.8)	10
	Ensure availability and sustainable management of water and sanitation for all	Clean drinking water (p.8)	
		Sanitation (p.8)	
		Water infrastructure (p.8)	9
		Water conservation (p.8)	12
	Ensure access to affordable, reliable, clean energy for all	Access to (clean) energy (p.9)	13, 1
		Transition from fossil to clean energy (p.9)	13
		Energy efficiency (p.9)	9, 13
	Promote decent work for all and sustainable economic growth	Developed world jobs (p.9)	1
		Developing world jobs (p.9)	1
		Fair trade and ethical supply (p.9)	1
	Build resilient infrastructure; promote sustainable industrialization and foster innovation	Digital infrastructure (p.10)	
		Sustainable physical infrastructure (p.10)	9
		Technology and technology transfer (p.10)	8
		Small enterprise lending (p.10)	17

SUSTAINABLE DEVELOPMENT GOALS

IMPACT THEME FRAMEWORK V1.1

	U.N. PRIMARY SDG	TONIIC IMPACT THEME	U.N. ADDITIONAL SDGs
10 REDUCED INEQUALITIES	Reduce inequality within and among countries	Equality (p.10)	
		Refugees (p.10)	16
		Social justice (p.10)	16
11 SUSTAINABLE CITIES AND COMMUNITIES	Make cities and human settlements inclusive, safe, resilient and sustainable	Affordable housing (p.11)	1
		Community empowerment (p.11)	
		Green building (p.11)	12
		Homelessness (p.11)	
		Smart cities and mobility (p.11)	
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Ensure sustainable consumption and production patterns	Circular economy (p.12)	9
		Environmental health (p.12)	3, 11
		Resource efficiency (p.12)	
13 CLIMATE ACTION	Take urgent action to combat climate change and its impacts	Climate adaptation strategies (p.13)	
		CO2 harvesting and storage (p.13)	15
		Greenhouse gas reduction (p.13)	7
14 LIFE BELOW WATER	Protection and sustainable use of marine resources	Aquatic sustainability (p.14)	6
		Sustainable fisheries (p.14)	1
		Sustainable aquaculture (p.14)	12
15 LIFE ON LAND	Protection and sustainable use of land resources	Animal welfare (p.15)	2, 6, 12, 13
		Sustainable managed landscapes (p.15)	13
		Biodiversity and conservation (p.15)	8
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Promote peaceful and inclusive societies, provide access to justice, and provide strong institutions	Policies and governments (p.16)	17
		Culture and the arts (p.16)	
		Media (p.16)	
		Conflict resolution (p.16)	16
17 PARTNERSHIPS FOR THE GOALS	Work together for sustainable development	Financial system change (p.17)	
		Blended capital (p.17)	
		Building the impact ecosystem (p.17)	8

" Toniic SDG Impact Theme Framework " , toniic, Sep 18 2019, https://toniic.com/sdg-framework/

United Nations Headquarters in New York, USA

WHAT ARE THE SUSTAINABLE DEVELOPMENT GOALS?

The Sustainable Development Goals are part of the United Nations 2030 Agenda.

The United Nations' sustainable development agenda began in 1998 and was implemented for the period 2000-2015 with the establishment of the Millennium Development Goals (MDGs). The MDGs were followed by the Sustainable Development Goals (SDGs) for the period 2015-2030, which were defined through discussions between the 193 member states of the United Nations (UN) and civil society.

The 2015-2030 Agenda covers 17 themes organized into 17 Sustainable Development Goals, all interconnected and interdependent, based on the three pillars of sustainable development: economic development, social integration and environmental protection.

Each Sustainable Development Goal has several targets, 169 in total, the equivalent of tactical variations of the goal, and each target has one or several indicators. These indicators, grouped into three types, make up a system for measuring progress, often macroeconomic:[1]

1 "Tier Classification for Global SDG indicators", United Nations, March 29, 2021, https://unstats.un.org/sdgs/iaeg-sdgs/tier-classification/

- The 130 Level I indicators are clearly defined and have internationally established methodologies for which standards are available. Data are regularly produced by at least 50% of the countries and population in the regions for which they are relevant.
- The 97 Level II indicators are clear and also have internationally established methodologies, but data are not regularly produced by countries.
- The 20 Level III indicators are those for which there is, to date, no internationally established methodologies or standards available. However, efforts are being made to develop or test methodologies and define common standards.

Four of these indicators are found in several levels due to their disaggregation.

In addition to their institutional aspect, which commits, but does not constrain, the Member States while relying on a "Global Partnership for Sustainable Development", these 17 Sustainable Development Goals constitute a framework for orientation and a common reading grid allowing the management of strategies specific to each stakeholder.

As well as relying on States and international organizations, the implementation of the Sustainable Development Goals relies on multi-stakeholder partnerships to mobilize and share expertise, technologies and financial resources.[2]

Thus, many United Nations bodies, and also regional bodies such as the European Union or the African Union, and national and sectoral bodies, are inspired by this framework to define their priorities and means of action according to the characteristics of their territories and their activities. The private sector and economic actors are largely concerned, and have specific orientation frameworks and initiatives for integrating the 17 Sustainable Development Goals into their strategies, allowing them to precisely measure their contributions to achieving them.[3]

This dimension, inclusive of all stakeholders, public, private and civil, is reflected in the Financing Strategy established by the United Nations General Secretariat for the period 2018-2021. This strategy is composed of three major axes: the alignment of public policies and the financial system with the Sustainable Development Goals; the implementation of financing and investment mechanisms adapted by region and by country;

2 SDG 17 Target 16: "Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries", https://sdgs.un.org/goals/goal17

3 These guidelines and tools are gathered under the SDG Compass project, implemented by the Global Reporting Initiative - GRI, the UN Global Compact, and the World Business Council for Sustainable Development - WBCSD, https://sdgcompass.org/

and **the contribution of innovation processes, both in terms of products and technologies, to ensure equitable access to financing for all stakeholders**.[4]

It is through this third strategic axis that blockchains are today being considered, both for their capacity to transform the financial system, and for the traceability, immutability and ease of access to the data to which they contribute.

In face of this strategy, several voices are already being raised to denounce an overly techno-centric approach to the solutions envisaged.

The risk is that of widening the inequalities between populations equipped and trained in digital practices and those not so equipped, and the encouragement of overconsumption of computer equipment that requires scarce resources, and whose life cycle to date is highly polluting.

Thus, the international consensus is both the strength and the weakness of this 2030 Agenda for Sustainable Development. In order to bring together all the stakeholders, it has been necessary to agree on an interpretation of the modalities of sustainable development that is sometimes inconsistent with the scientific and social findings on the limits of our models of society.

In this context, the system of Sustainable Development Goals must be considered for what it is, **a system for measuring progress, common to 193 countries, with which to acknowledge the scope and urgency of global issues, and a common framework**.

The Sustainable Development Goals can also form the basis for social and technological innovations whose ambitions cannot be limited to existing indicators.

If the Sustainable Development Goals are a system for measuring progress and blockchains are a system for exchanging value without intermediaries, what does their conjunction look like? Before we get to that, let's start by defining what a blockchain is.

4 "Synopsis: The Secretary-General's Strategy for Financing the 2030 Agenda for Sustainable Development (2018 –2021)", https://www.un.org/development/desa/financing/fr/node/837

WHAT IS A BLOCKCHAIN?

A blockchain is to value transfers what the web is to information exchange

A public blockchain, accessible to all, is to the transfer of value what the web is to the transfer of information. In other words, public blockchains have the same impact on the international monetary system as the internet and the web have had on the media and information. Just as the Internet and the Web have ended the media's monopoly on public speech, blockchains are ending the states' monopoly on money, or at least on the transfer of value.

Just as it was impossible in 1995 to imagine the upheaval induced by the advent of information and communication technologies on society, then analog, it would be presumptuous to want to describe with acuity the upheaval being induced by the advent of peer-to-peer electronic cash system within our societies which, since the advent of the Internet, are digitizing at great speed.

The Internet has renewed the way we exchange information and communicate. Today, 4.2 billion people have a connection to the network and use several of these services on a daily basis, such as e-mail, instant messaging and the World Wide Web.

These services are based on communication protocols that transmit and copy information and data over the Internet from point A to point B, using paths on the network where the information is broken down into packets of data so that the message is reconstituted when it reaches its destination.

For example, when a person sends an e-mail, the message is copied from the sender's mailbox to the recipient's mailbox. When someone accesses a web page, the content is copied from the server where it is hosted to the browser of the person accessing it.

The major innovation brought by the Bitcoin blockchain and public blockchains in general is based on the idea that from now on, **specifically unique information can be transmitted via the Internet**. This information, because it is unique, becomes a digital asset whose particularity is that it can be exchanged without being duplicated. Indeed, if one person sends a bitcoin to another person, this "information" is not duplicated, it is de-registered from the sender's account and registered in the recipient's account. The ledger is public and all transactions can be verified.

When Satoshi Nakamoto published the seminal paper "Bitcoin: A Peer-to-Peer Electronic Payment System" in November 2008, he provided an answer to the so-called double-spending problem that had long puzzled mathematicians and computer scientists.

bitcoin and Bitcoin?

Created by a person, or group of people, under the pseudonym Satoshi Nakamoto, the Bitcoin network has been in operation since January 3, 2009. While "Bitcoin" with a capital B refers to the network, the protocol and the software that runs it, "bitcoin" refers to the token* that is traded on the network.

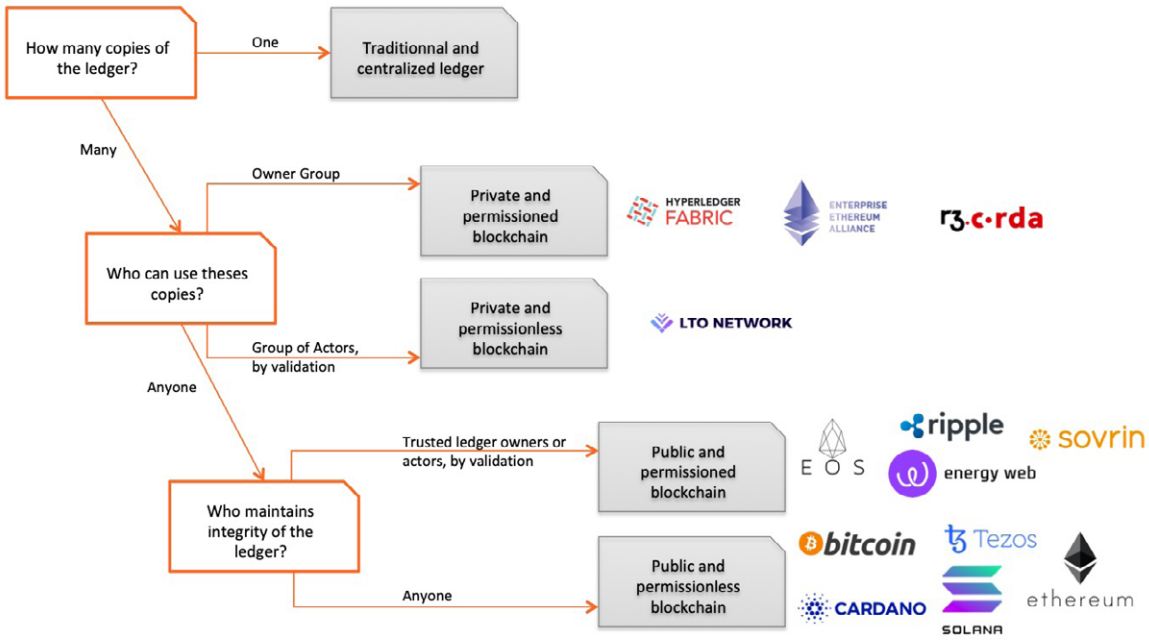
Bitcoin is a digital currency that is exchanged in a peer-to-peer manner, meaning that it does not go through a government, bank or any other intermediary. Transactions are validated by certain nodes of the network, called miners. The mining operation consists of validating transactions per block by performing a cryptographic calculation called "proof-of-work". This operation, which consumes a lot of energy, is one of the cogs in the wheel that secures transactions on the network and generates new bitcoins.

Computers involved in mining compete to validate new blocks of transactions every ten minutes, but only the first to find the cryptographic hash* is paid, currently 6.25 bitcoins. If, until 2017, China was the country concentrating the majority of miners, the government has sounded the death knell of this activity, encouraging them to relocate their activities elsewhere, including Canada, Russia, Eastern Europe or Iceland.

Bitcoin issuance is limited to 21 million units, each divisible to the eighth decimal place. At the time of publication of this report, in September 2022, some 19.1 million Bitcoin are already in circulation, and the last one will be generated around 2140.

No one owns the Bitcoin network, and the governance for evolving the source code is sometimes complex. Since Bitcoin's source code is open source, anyone can take it over, modify it and use it. But the point of Bitcoin is that it is a network, and to validate transactions on this network, a community of miners must participate in the validation of transactions.

To evolve the Bitcoin software consensus mechanism, a majority of miners must agree on the validity and interest of a new version of the software. This mechanism can cause tensions and sometimes even a split between the original version, carried by some miners, and a modified version, carried by others. This split into two blockchains, called a hard fork*, is the origin of new crypto-assets such as Bitcoin Cash or Bitcoin Gold.



Distributed Ledger Taxonomy

Source: Amended version from Blockchain for Good in: amended version from Dave Birch (Consult Hyperion) in: UK Government Office for Science report " *Distributed Ledger Technology: beyond block chain* ".

This problem, until then unsolvable, had always prevented the creation of a digital currency, which, as a matter of principle, could have been copied. **With the invention of Bitcoin, for the first time since the beginning of computing, ownership of a digital asset can be transferred without being duplicated or going through a centralized registry**.[1]

Until the advent of Bitcoin, the only way to exchange money without going through the banking network or any financial intermediary was to use cash, in fiat currency*. The fundamental innovation of the Bitcoin protocol, and later of Ethereum and some other crypto-assets, is that it is, in the literal sense of the word, electronic cash, and more broadly, a system for exchanging value without intermediaries.

To try to explain the technologies discussed in this report in a simple way, we propose a framework, in the form of three questions, which will allow the reader to understand a blockchain project for what it is, and to understand if the initiative implements a public, common, open to all blockchain or if it is a project of another type.

These three questions are: 1. How many copies of the registry exist? 2. Who can access and use the registry? and 3. Who maintains the integrity of the distributed registry? (See graphic *supra*).

Depending on the answer to each of these questions, there are four main types of blockchains:

1 "Bitcoin, la monnaie acéphale", Jacques Favier, Adli Takkal Bataille, CNRS Edition, May 24, 2017.

1. **Public permissionless blockchains**, public blockchains not requiring permission, such as Bitcoin, Ethereum or Cardano, allow anyone to read, write, and validate data.
2. **Public permissioned blockchains**, public blockchains requiring permission, such as Eos, Ripple, Energy Web Foundation or Sovrin, allow anyone to read and write data, but only certain nodes of the network can validate transactions.
3. **Private permissionless blockchains**, private blockchains not requiring permission, such as LTO, allow anyone to join the network, create a node and participate in the validation of transactions, but the people who can read and write the content of the blockchain are restricted.
4. **Private permissioned blockchains**, private blockchains requiring permission, such as Morpheus Network or Corda, only allow a single operator or a network of operators to read, write and validate data.

Public permissionless blockchains are to fiat currencies (the dollar, the euro, the yuan, etc.) what the World Wide Web was to the media in the 2000s: **the loss of a secular monopoly**.

Bitcoin is the first public permissionless blockchain, created in 2008 and implemented in 2009 in the geopolitical context of the greatest financial crisis the world has seen since 1929, marked by a loss of confidence in banks, institutions and States, and whose rescue, then stimulus and finally austerity plans caused public debt to explode and further aggravated the rise in unemployment as well as the increase in inequality in the most developed countries. The global Covid-19 pandemic has once again accelerated the massive recourse to money creation and debt.

Bitcoin was not created from scratch. It is the result of research and trial and error of various kinds, including the cryptographic work proposed in the 1990s by Haber and Stornetta, and that by Nick Szabo, a computer scientist, lawyer and cryptographer, who in 2005 proposed a monetary exchange system based on validation by proof of work, from which the so-called Satoshi Nakamoto(s) was probably inspired.

Today, it is common to distinguish between three or even four[2] generations of public permissionless blockchains:
1. **First generation blockchains**, which are characterized by the type of consensus mechanism implemented (see below), in this case the Proof of Work* consensus mechanism. **Bitcoin**.

2 “The Four Blockchain Generations”, Stephen Cummings, Medium, February 2, 2019, https://medium.com/the-capital/the-four-blockchain-generations-5627ef666f3b

2. **Second-generation blockchains** that implement smart contracts*, such as **Ethereum**, and whose ambition is to "create a decentralized, autonomous and censorship-resistant global computer".[3]

The first and most used of these to date was invented in 2015 by a team of computer developers gathered around Vitalik Buterin. Named Ethereum, this common blockchain allows the creation of "smart contracts*", or, according to its inventor, "persistent scripts".

These smart contracts* make it possible to verify and enforce mutual agreements that are recorded and publicly available in the Ethereum blockchain. The advantages of these contracts are that they are replicated in all nodes of the Ethereum network and that their execution is autonomous and does not go through a trusted third party. Ethereum uses Solidity, a Turing-complete programming language, which means that it can be used to program all the functions that can be computed in the Turing sense, i.e. almost all the functions known in modern programming languages, and

3. **Third-generation blockchains** that rely on less energy-consuming consensus mechanisms other than proof of work, and that allow the deployment of smart contracts, solve scalability problems and natively integrate the possibility of carrying out transactions between different blockchains.

This is the case for **Cardano**, **Nano**, **IOTA** or **Polkadot**.
In other words, whilst Bitcoin allows individuals to carry out simple transactions without going through a trusted third party, Ethereum and the second and third generation blockchains allow the programming of much more complex financial interactions without going through a trusted third party.

Building from these common blockchains whose source code is freely accessible, other fourth-generation distributed ledgers and blockchains have been derived whose rules for writing, reading and validating transactions are rewritten, and whose open, decentralized and common character is partially or completely missing.

Public permissioned blockchains, such as **Eos**, **Ripple**, **Energy Web** or **Sovrin** are blockchains that anyone can read, on which anyone can write data, but only certain nodes of the network validate transactions. These blockchains are notably used by public institutions such as government agencies or business consortiums.

Finally, **private permissionless blockchains** such as **LTO Network** (corporate blockchain) and private permissioned blockchains such as **Morpheus Network** (logistics), **Patientory** (medical supply) or **Corda of R3** (banking) are restricted in writing/

3 "A Gentle Introduction to Ethereum", Antony Lewis, Bits On Blocks, October 2, 2016, https://bitsonblocks.net/2016/10/02/gentle-introduction-ethereum/

reading/validating transactions to the entities who set them up.

What makes a distributed registry interesting is that it distributes trust on the network. As soon as trust is placed in the hands of a small group of people or organizations, this type of distributed ledger loses one of its fundamental qualities: that of not needing a trusted third party to perform and validate peer-to-peer transactions. Phil Chen, general manager in charge of decentralization at HTC Exodus, believes that *"In the enterprise space, people are talking about private blockchains, which technically are not blockchains but a better database management system. Nevertheless, it does have productivity gains; I call it a 9 to 10 innovation, whereas public blockchains like Bitcoin and Ethereum are 0 to 1 innovations that completely change the way we think and use money and computation".*[4]

Still, it turns out that private blockchains are allowing consortia of companies and groups of players to experiment with new forms of organization and data transfer that are sometimes proving to be far more efficient than before, if not for the fact that governance is returning to a few.

Decentralization and Governance

For Vitalik Buterin, the founder of the public blockchain Ethereum, "blockchains are politically decentralized (no one controls them) and architecturally decentralized (no infrastructural central point of failure) but they are logically centralized (there is one commonly agreed state and the system behaves like a single computer)".[5] Architectural centralization concerns the question of how many physical computers the system consists of. Political centralization considers how many individuals or organizations have ultimate control over the computers that make up the system. Logical decentralization is about whether "the interface and data structures that the system presents and maintains are more like a single monolithic object or a shapeless swarm",[6] i.e., what happens if we split the system in two? Do both halves continue to function as autonomous units?

Blockchains therefore make a new contribution by embedding in their model the principles of validation, transparency and security of transactions without a trusted third party being in charge.

But just because the trusted third party disappears does not mean that the issue of governance disappears as well.

4 "What is the Difference Between Blockchain and DLT?", Braun Wiliam, Meidum, October 21, 2019, https://medium.com/@wiliambraun427/what-is-the-diff-erence-between-blockchain-and-dlt-c2124974f7ec
5 "The meaning of Decentralization", Vitalik Buterin, Medium, February 6, 2017, https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274
6 *Ibid.*

On the contrary, warns researcher Primavera De Filippi, "*to remain decentralized, the (public) blockchain needs governance*".[7]

For the researcher, "*public blockchain is a decentralized technology. But we cannot expect regulation to push for decentralization (...) The only lever would be a reflection on governance. How can we create a decentralized system but with coordination that remains decentralized? How can we set up a consensus, for example, whereby everyone agrees to invalidate a transaction? Knowing that we have not found the answer for the Internet, it will be difficult to find one for the blockchain. One thing is certain: the devil is not in the middle. Blockchain could rely on some intermediaries as long as they do not become monopolistic. It is this bias that we must guard against, if we look at what the Internet has become, dominated by giants*".[8]

In order to be accessible to as many people as possible, we have endeavored throughout the writing of this report to document as precisely as possible the technical functioning of the blockchain projects and initiatives identified. Many of these projects implement smart contracts, decentralized applications or are constituted as a Decentralized Autonomous Organization, which we will define further on.

Moreover, rather than dwelling on technical explanations of how blockchains work, we have preferred to create a glossary that will allow the reader who is unfamiliar with these technologies to refer to a technical explanation linked to the study of a use case, thus allowing them to understand the mechanisms at work in a concrete and operational way.

7 "Pour rester décentralisée, la blockchain a besoin d'une gouvernance prévient la chercheuse Primavera De Filippi", Émilie Laystary, France 24, July 1, 2018, https://www.france24.com/fr/20180701-rester-decentralisee-blockchain-a-besoin-dune-gouvernance-previent-chercheuse-primavera-filippi
8 *Ibid.*

What is a Smart Contract?

A smart contract is like a vending machine. The metaphor used by the Ethereum.org website is telling: "*A smart contract is like a set of rules that lives on-chain, in plain sight, and operates exactly according to those rules. Imagine a vending machine: if you provide it with enough funds and enter a selection, you will receive the drink you want. And like vending machines, smart contracts can hold funds just like your Ethereum account. This makes it possible to schedule deals and transactions*".[9]

A smart contract is "an application that runs exactly as programmed, without the possibility of stopping it, uncensorable, without possible fraud and without third-party interference".[10]

The interest of these contracts is that they are autonomous, replicated in all the nodes of a blockchain, and that their execution does not require a trusted third party to guarantee their validity. Several public second and third generation blockchains allow the programming of smart contracts*, including **Achain**, **BitShares**, **Eos**, **Ethereum**, **Neo**, **Nem**, **NXT**, **Omni**, **Ontology**, **Qtum**, **Stellar** and **Waves**.

What is a Decentralized Application (dApp)?

According to Andreas Antonopoulos, a decentralized application includes "*one or more smart contracts deployed on one or more blockchains, a transparent user interface, a distributed data storage model, a peer-to-peer message communication protocol and a decentralized name resolution system*".[11]

Once deployed on a public blockchain like Ethereum, the computer code of a decentralized application (dApp) cannot be deleted or stopped, allowing anyone to use its functionality.

This means that even if the person or group of people behind the application disappears, the decentralized application will continue to function.

According to a study conducted by the Binance platform, "*66% of dApps users are using decentralized finance applications, with the majority of users being in Asia*".[12]

9 "Introduction to smart contracts", Ethereum, July 25, 2022, https://ethereum.org/fr/smart-contracts/
10 *Ibid.*
11 *Ibid.*
12 "2021 Global Crypto User Index", 2020, https://research.binance.com/static/pdf/Global_Crypto_Index_2021.pdf

What is a Decentralized Autonomous Organization (DAO)?

A DAO is a technical way for people to organize themselves around a common purpose without centralized direction. They are often called "*Internet forums with a shared bank account*".[13]

They have no legal personality in the legal sense. They are "quasi-corporations" that operate on public blockchains or via decentralized applications and smart contracts. **A DAO is an organization of people operating through a computer program that provides governance rules to the community without centralized direction**.

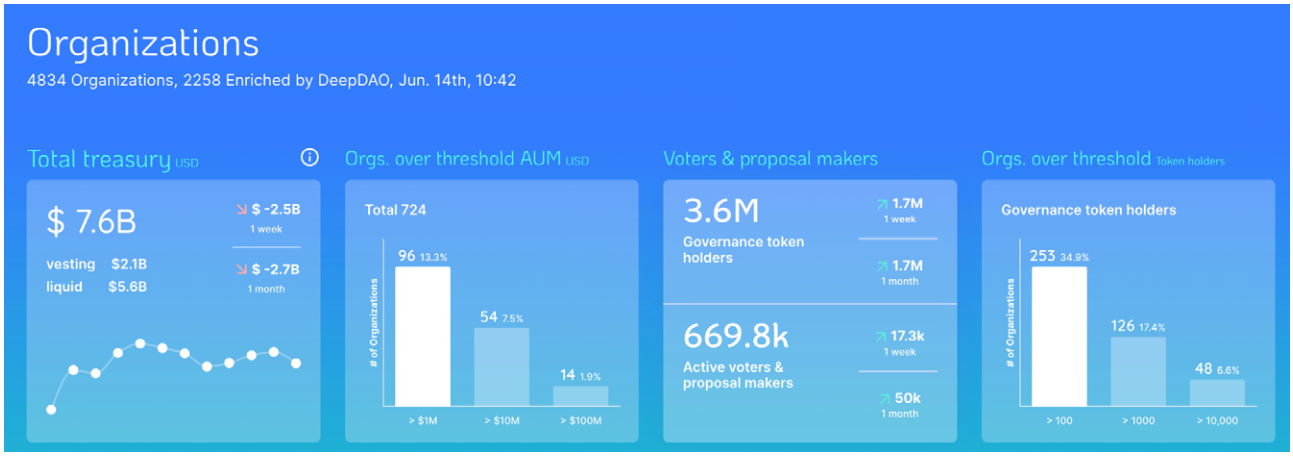
These rules are transparent and immutable because they are encoded in a blockchain protocol. The first DAO dates back to 2016 and raised $150 million on the public Ethereum blockchain. It lost a third of its balance in a hack before even a single cent was spent, and this ended in a fork*, the split of the Ethereum blockchain from Ethereum Classic, meaning that the blockchain was rewritten to undo the hacking, thus undermining the very principle of its immutability. [14].

Between 2016 and 2018, only a dozen DAOs were created. In 2020, their number increased to 200, and by June 2022, there were just under 5,000.

According to the news site stg.deepdao.io, these 4,834 DAOs have raised a total of $7.6 billion, the governance of which is distributed among 670,000 voters (Graphic 1).

Currently, the largest DAO is Uniswap, a decentralized trading platform that automatically makes markets for liquid asset pairs. The DAO* has 334,000 members as of June 2022 (Graphic 2).

13 "AssangeDAO Raised $56M and Quickly Split Up. Was It Still a Success ?", Daniel Kuhn March, Yahoo, July 8, 2022, https://finance.yahoo.com/news/assangedao-raised-56m-quickly-split-210057108.html
14 "De l'inviolabilité d'une blockchain", Jacques-André Fines Schlumberger, *La revue européenne des médias et du numérique,* N°40 Autumn 2016, https://la-rem.eu/2017/02/de-linviolabilite-dune-blockchain/



Graphic 1. 4,834 DAOs with a total cash flow of $7.6 billion with governance divided among 670,000 voters. Source: https://stg.deepdao.io

rank	organization	treasury	last 24hrs	top treasury tokens	main treasury chain	governance token holders	active members	proposals	votes
1	Uniswap	$1.6B	-16.4%			334k	8.7k	83	37k
2	BitDAO	$1.1B	-9.1%			18.8k	74	10	200
3	Gnosis	$1B	-19.2%			19k	2.9k	44	17.8k
4	UXDProtocol	$382.7M	-0.6%			6.8k	65	435	1.8k
5	Polkadot	$323.4M	-20%			978.8k	38	281	1.7k

Graphique 2. The Uniswap DAO has 334,000 members as of June 2022. Source: https://stg.deepdao.io

Bitcoin's Energy Expenditure

A public blockchain is a peer-to-peer network. A peer-to-peer computer architecture is one that allows exchanges between several computers connected to the system without going through a central server. All the computers are called "nodes" and play the role of both client and server, i.e. the role of sender and receiver.

The question is therefore how do the nodes of a permissionless public blockchain trust each other and accept new blocks of transactions released on the network? How do you spot potential rogue nodes that try to register false transactions for their benefit in the public ledger? In order to agree on the same public register, these blockchains rely on a "consensus mechanism" (also called consensus protocols or algorithms) that allows them "to agree in a distributed way".

There are several consensus mechanisms, including the so-called "proof of work" and "proof of stake" mechanisms. While the latter does not consume more energy than a conventional computer system, the former is the subject of lively debates aimed at "the blockchain" as a whole without really distinguishing the two mechanisms.

On the Bitcoin blockchain, new blocks are created by certain nodes in the network called miners. They make their computing power available to the system to solve a complex mathematical problem whose principle is to find a hashed number that respects certain constraints (see hash function*). As it is impossible to predict the result of the hash in advance, the set of computers that mine calculates all the possibilities to arrive at the result.

This operation, called validation by the "proof-of-work consensus mechanism", can only be obtained by carrying out a task that consumes a lot of computing power, and therefore energy.

The system is designed in such a way that an attacker would have to control more than 50% of the computing power of all the computers in the world that are mining in order to modify a block without anyone knowing. And that's why, since 2009, Bitcoin has never been hacked. Moreover, the difficulty of the mining is automatically adjusted according to the number of computers hashing, so that a new block is generated on average every ten minutes. Each time a computer finds the right answer, the block is created and the miner is paid in bitcoins.

This is how the creation of bitcoin units of account is programmed. The protocol was designed so that bitcoins are created gradually without a central authority. The computer code also specifies that the more the chain grows, the more difficult it becomes to mine Bitcoins, and the more

the payout decreases. While in the early days of Bitcoin individuals could mine on their own computers, the computing power required today is such that they are supplanted by companies that run thousands of servers in warehouses.

The debate about the energy impact of blockchains therefore pits those who consider that "Bitcoin consumes too much energy" against those who reply that "Bitcoin is secure because it consumes a lot of energy". This misunderstanding prevents us from asking the essential question about its usefulness. Is Bitcoin's energy consumption worth the service it provides? Is a universal, incensurable monetary system, open to all, worth the energy expenditure of the consensus mechanism needed to secure transactions? As we have just seen, it is because Bitcoin consumes energy that it is secure. And, according to the Cambridge Bitcoin Electricity Consumption Index (CBECI), "higher electricity expenditures tend to increase network security, as attacks become more costly". The question might even be why would anyone want to make Bitcoin less energy-intensive if that energy expenditure is precisely to secure transactions on the network.

Moreover, it is essential to distinguish between electricity consumption and the environmental footprint of Bitcoin.

While electricity consumption refers to the total amount of electricity used by the bitcoin mining process, the latter refers to the environmental externalities of bitcoin mining. "What ultimately matters for the environment is not the level of electricity consumption per se, but the carbon intensity of the energy sources used to generate that electricity",[15] explains the Cambridge Bitcoin Electricity Consumption Index (CBECI). As it turns out, the mining industry is probably the one that relies the most on renewable energy. Not because of ecological awareness, but because the mining industry is portable, mobile, cyclical and relies on economic opportunism solely related to the cost of electricity, the cheapest of which is now renewable energy.

"*Bitcoin is even accelerating the transition to renewable energy*" explains Louis Bertucci, a researcher at the Louis Bachelier Institute. "*The proof-of-work mechanism generates a strong demand for cheap electricity. Between 2009 and 2018, the value of bitcoin rose sharply, but miners' income, in absolute terms, was still low. Miners did not have to make the effort to use the cheapest energy possible and used the energy they had available. In contrast, in recent years the price of a bitcoin has been rising less steeply, and miners are making about $15 billion a year*[16]*.*

15 "Environmental Implications", Cambridge Centre for Alternative Finance, Website home page, retrieved June 15, 2022, https://ccaf.io/cbeci/faq
16 "Bitcoin miners generated more than $15 billion in revenue during 2021", Michael McSweeney, December 23, 2021, https://www.theblock.co/linked/128475/bitcoin-mining-2021-revenue

With the mining market booming, some miners, such as Big Block Data Center, [17] *have a real incentive to finance renewable energy production unit projects (hydraulic, solar, geothermal, etc.), and thus benefit from an energy whose marginal cost is a priori lower than that of fossil fuels*". [18]

GEM Mining[19] and Foundry[20] , two American mining companies, claim to use 97% and 71% renewable energy respectively in their activities, because it is the lowest cost electricity.

Also according to Louis Bertucci, Bitcoin helps to stabilize certain power grids: "*Miners who plug into existing power grids can easily 'fade' during power peaks. If the power grid operator detects a power spike and an overload, it sends a message to the miners, who can shut down their machines almost at a second's notice. As soon as the peak consumption is absorbed, the miners can resume their activity. The cost of stopping/restarting the machines is extremely low. Indeed, whether they mine in the morning, evening or night is of little importance to them, as long as they mine a certain number of hours per day. And this, of course, can be the subject of contracts between the miners and the energy producers* ".[21]

According to a University of Cambridge study published in 2020, the energy expenditure of Bitcoin mining amounts to 130-147 TWh, or about 0.6% of the electricity generated worldwide.

A survey by the Bitcoin Mining Council[22] shows that in the first quarter of 2022, Bitcoin miners use 64.6% sustainable energy, defined as wind, solar, hydro or nuclear, and estimates that "*using conservative assumptions about the energy mix, Bitcoin mining as a whole uses an estimated 58.4% sustainable energy*". [23]

Finally, Bitcoin's detractors are only interested in Bitcoin's energy consumption, and very little in the Lighting Network* Layer 2 (see Peer-to-Peer Electronic Cash System and Programmable Money) which allows transactions and micro-transactions to take place at low cost and without energy expenditure.

17 Big Block Data Center : https://bdatacenter.fr/en/home/
18 Talk with Louis Bertucci, 30 juin 2022.
19 GEM Mining, Website home page : https://gemmining.com/overview/
20 Foundry Digital, Website home page https://foundrydigital.com
21 Talk with Louis Bertucci, 30 juin 2022.
22 "We Welcome all Bitcoin miners to join", Bitcoin Mining Council, Website home page, retrieved June 15, 2022, https://bitcoinminingcouncil.com/
23 "Response to the Huffman Lette", Bitcoin Mining Council, May 2, 2022, https://bitcoinminingcouncil.com/

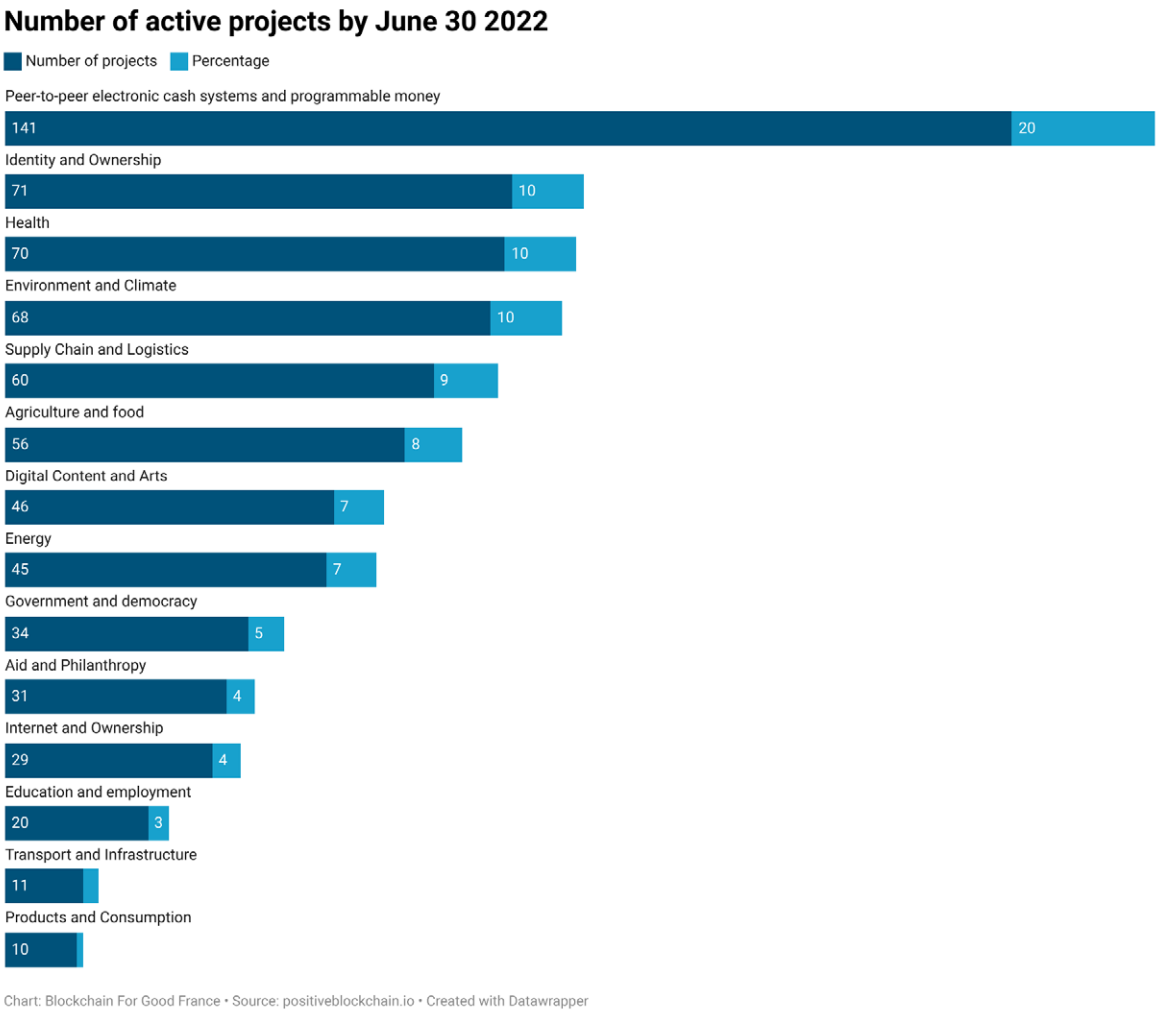
GLOBAL OVERVIEW

This report is based on the Positiveblockchain.io open data directory

Creation of the directory: 2018
Number of projects in the directory in July 2022: 1,273
Number of active projects: 692
Number of inactive projects: 581

PB PositiveBlockchain.io

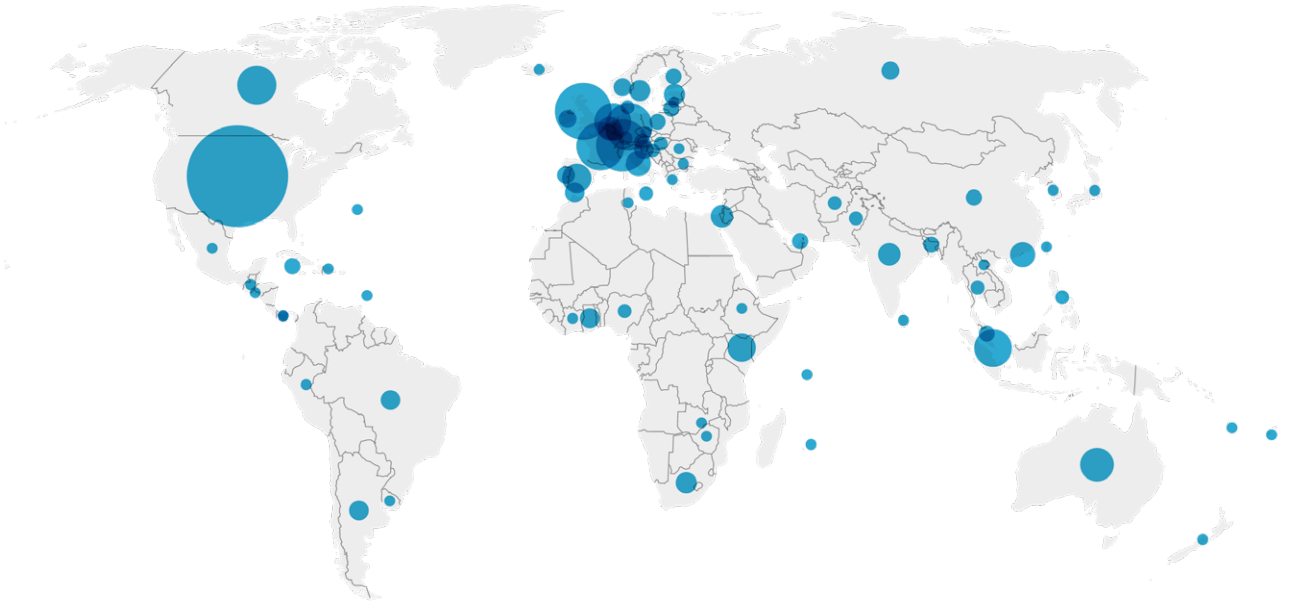
Number of active projects by June 30, 2022



The distribution of projects among the fourteen categories of the directory shows that, not surprisingly, “Peer-to-Peer Electronic Cash systems and Programmable Money” is the category that contains the most projects, almost twice as many as the next two categories, “Identity and Ownership” and “Health”. Indeed, Bitcoin, implemented in 2009, is first and foremost a peer-to-peer electronic money system, open to all, without prior authorization or censorship.

The themes of digital identity and property registry have 71 active blockchain initiatives, which also testifies to the growing interest in decentralized identity and the paradigm shift it implies, as discussed in the “Identity and Ownership” chapter. Contrary to popular belief, blockchains do not automatically lead to high energy expenditure and 68 projects are directly involved in the fight against climate change and environmental preservation, as most of these projects are built on blockchains with low environmental impact (see the “Environment and Climate” chapter).

Geographic distribution of actie projects by june 30, 2022
By country, headquarters



The geographic distribution of project headquarters shows a clear dominance by the United States. The next nine countries are Australia, Singapore, Canada, the Netherlands, France, Germany, Switzerland and the UK.

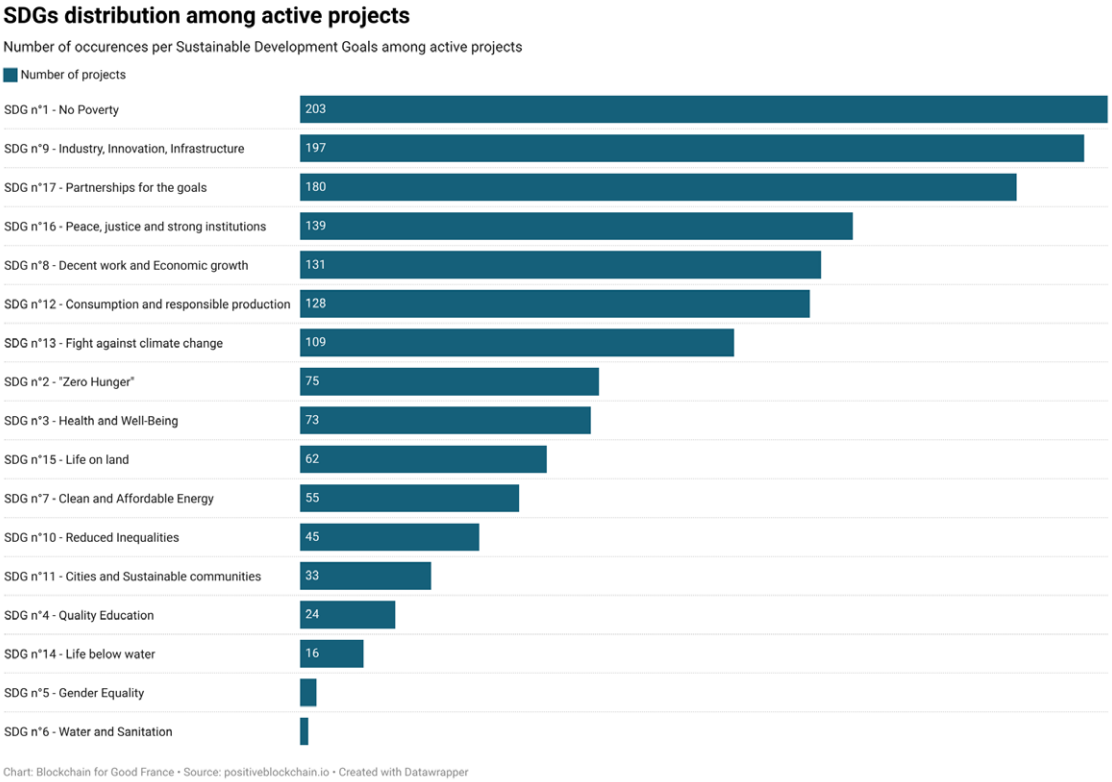
It should be noted, however, that this map does not show the countries in which these blockchain initiatives are deployed. Indeed, although many organizations are headquartered in countries in the northern hemisphere, many are developing activities in the southern hemisphere.

Indeed, it appears that blockchain initiatives have emerged all over the world, and that the rate of adoption of crypto-assets by the general public is growing fastest in Africa, Latin America and Southeast Asia, as we describe in the chapter "Peer-to-Peer Electronic Cash System and Programmable Money".

In addition, it should also be noted that this map does not show the projects that are not headquartered in any country, due to the decentralized nature of the initiative, such as some Decentralized Autonomous Organizations (DAOs*).

SDGs distribution among active projects

Number of occurences per SDGs among active projects



The 692 active projects in the directory show that the Sustainable Development Goal (SDG) with the most occurrences is SDG 1 “no poverty”. The reason this goal comes first is that it overlaps with many of the projects listed in the “Peer-to-Peer Electronic Cash system and Programmable Money” category, which has the most projects in the directory. Indeed, several subcategories of “Peer-to-Peer Electronic Money and Programmable Money” have a direct link with Sustainable Development Goal 1. These include “peer-to-peer transactions and payments”, “financial inclusion”, “participatory finance” and “basic income”.

To correlate the categories and subcategories of the directory with the Sustainable Development Goals (SDGs), we used the Toniic SDG Impact Theme Framework (see Methodology). It is important to note that the number of occurrences of Sustainable Development Goal 1 is also due to the presence of projects that do not primarily aim to fight poverty, but which *de facto* contribute to that goal. This illustrates the transversality of the Sustainable Development Goals.

The Sustainable Development Goal second-most addressed by active projects is SDG 9: “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation”. As its title indicates, this SDG covers a broad spectrum: sustainable and accessible infrastructure, socio-economically viable industrialization, access to financial services for all enterprises, modernization and sustainability of industrial sectors, innovation, research and development, support for developing countries, diversification and value addition, and finally, access to information and communication technologies.

Evolution of number of projects created per year

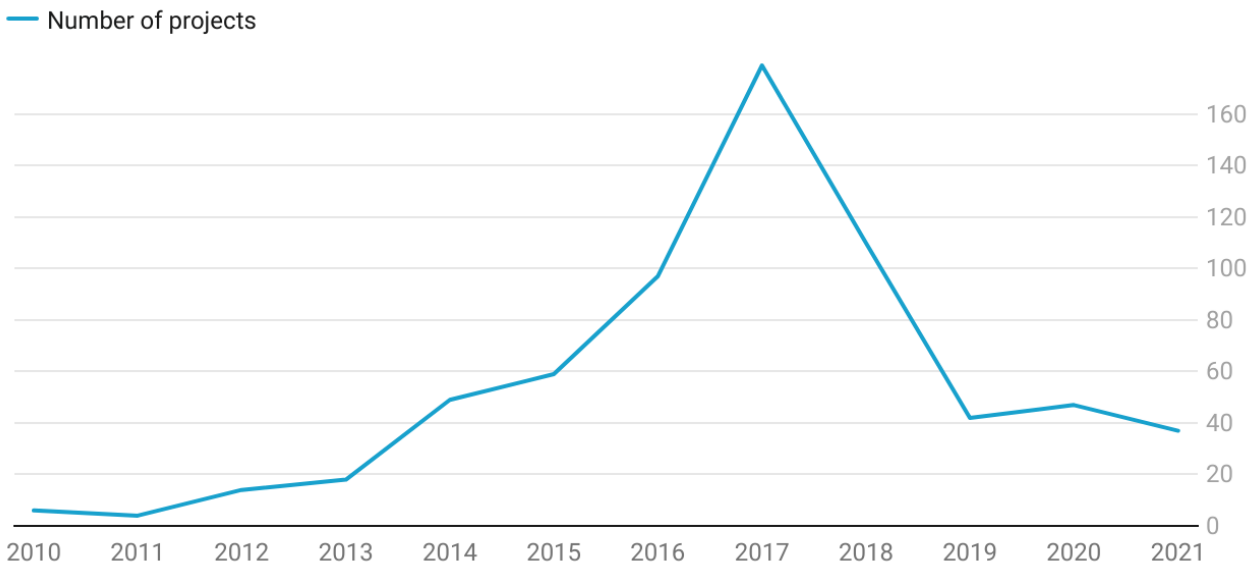


Chart : Blockchain For Good France

Source: positiveblockchain.io • Created with Datawrapper

The development of initiatives based on blockchains, whether or not they are related to the Sustainable Development Goals, seems to be linked to the development of second-generation blockchains, with Ethereum launching in 2015 and peaking at the beginning of 2018, coinciding with the fall in the price of bitcoin, whose valuation went from €16,000 to €6,000 in a few months.

In addition, the evolution of the number of projects resembles the five "hype cycles",[1] proposed by the firm Gartner: "Launch of Technology, Peak of Exaggerated Expectations, Chasm of Disillusionment, Slope of Enlightenment, Plateau of Productivity".[2] This "hype cycle" reflects the evolution of interest in a new technology, not its adoption.

1 "Blockchain Expectations and Realities From 2017 To 2021 And Beyond", Jorge Ordovás, August 30, 2021, https://business.blogthinkbig.com/blockchain-expectations-and-realities-from-2017-to-2021-and-beyond/
2 *Ibid.*

Distribution by organization type

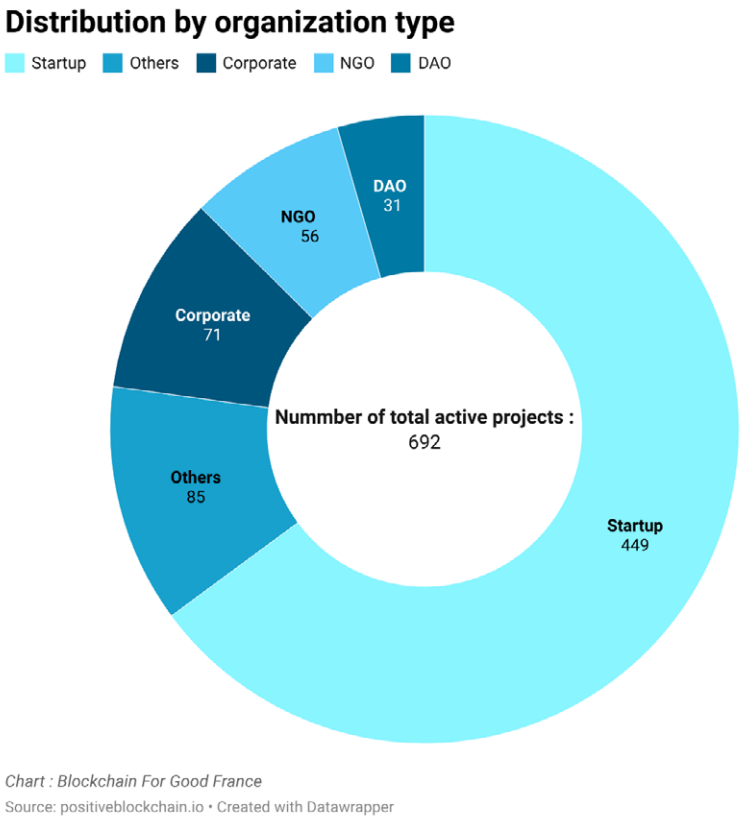
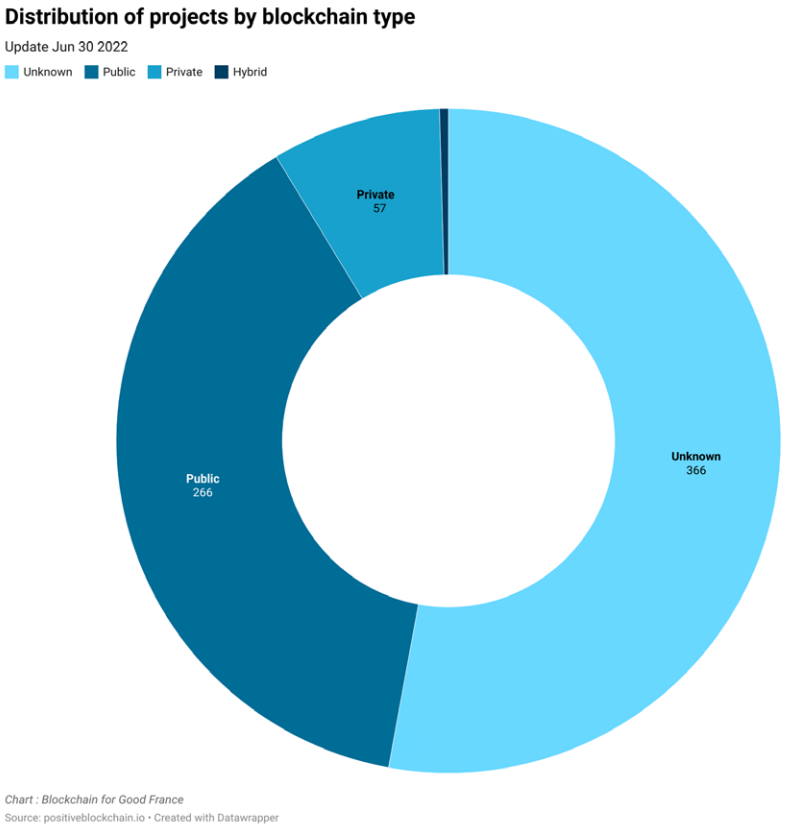


Chart : Blockchain For Good France

Source: positiveblockchain.io • Created with Datawrapper

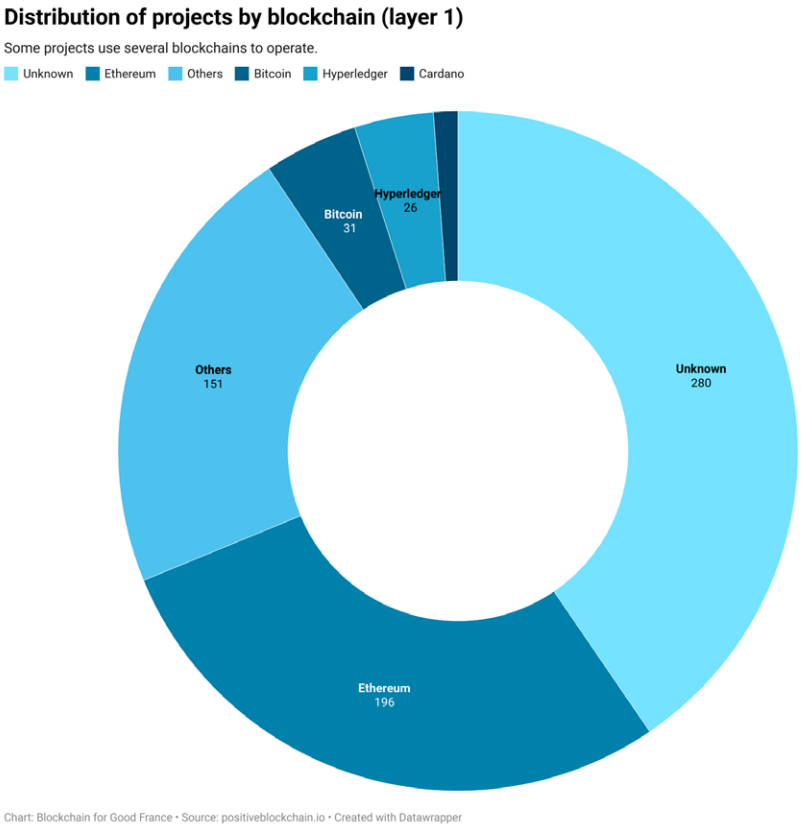
Of the 692 active projects in the directory, 449 are led by startups, or 65%. DAOs* account for only 4% of active projects, while 10% are led by companies. Finally, NGOs and non-profit projects account for 8% of said projects. Three-quarters of the blockchain projects in pursuit of one or more of the Sustainable Development Goals are therefore carried by the private sector.

Distribution of projects by blockchain type



Of the 692 projects listed in the directory, 266 are based on public blockchains and 57 claim to implement a private blockchain. It is interesting to note the considerable number of projects, 366, that claim to implement a blockchain without specifying which one or what type of blockchain is implemented. While it is likely that these projects are using a private blockchain whose governance is in the hands of authenticated and previously accredited partners, it is not possible to verify this information. This is a testament to the excitement surrounding certain blockchain projects that are in name only. If we look at the ratio of public blockchains to total active projects, it turns out that 38.5% of the projects in the directory are deployed on a public blockchain.

Répartition des projets par blockchain (Layer 1)



Among the active projects in the directory whose blockchain is public, Ethereum is the most used blockchain, followed by Bitcoin, then Cardano. The Ethereum blockchain, because of its precedence over the others, confirms its power of attraction to IT developers, and a fortiori, developers working on blockchain projects with social and environmental impact. According to a report published in 2021 by Electric Capital, "*more than 4,000 monthly active open source developers work on the Ethereum network*",[1] followed by the Polkadot, Cosmos, Solana, and Bitcoin communities.

Moreover, Ethereum is the most versatile public blockchain: it is possible to code smart contracts*, develop decentralized applications* as well as build DAOs*, while using Ether, its native crypto asset, as a payment method.

1 "Electric Capital Developer Report (2021)", Maria Shen, Medium, January 5, 2022, https://medium.com/electric-capital/electric-capital-developer-report-2021-f37874efea6d

IDENTITY & OWNERSHIP

IDENTITY & OWNERSHIP

Number of projects in the directory: 99

Number of active projects: 71

Name of active projects: Accredible ; Agrello ; Aid:Tech ; Archipels ; BenBen ; Bitfury Bermuda ; Bitfury Project in Georgia ; Bitnation ; Blockchain Helix ; BlockID ; brightID Bron.tech ; Chromaway ; Civic ; Crayonic ; Datafund ; Deloitte's Smart Identity ; Digiland Digital Bazaar ; Digitary ; EduCTX ; Empowa ; Golandregistry (UN in Afghanistan) Gravity ; Hala Systems ; ID2020 Alliance ; Iden3 ; Irisguard ; JOLOCOM ; Keeex Kilt ; Kleros ; Land LayBy ; LegitDoc ; Logion ; Mattereum ; Medici Land ; Netservice Open Time Stamps ; OpenCerts ; OriginStamp ; Polkadot ; Rohingya Project ; Safe Haven ; SecureKey and IBM ; Serto ; SESO ; ShareToken ; ShoCard ; Sovrin ; Spherity Spring Labs ; SpruceID ; Talao ; Thailand digital identity ; TiiQu ; Transcrypts ; Tykn Ubitquity ; Uniris ; UTU ; Veramo ; VERFiD Pet ; Verif-y ; veritise ; Vidchain ; WIN Woleet ; Wordproof ; Youbase / Cortex ; Zwei Space ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

What do blockchains bring to the fields of digital identity, land ownership, and certification of official documents?

How do blockchains renew the relationship between a country's citizens and their public administration and services,[1] local and global governance systems, and voting systems?

These are just some of the issues on which blockchain projects are challenging traditional schemes based on centralized governance, and one of which seems to us to be both central and transversal: digital identity.

All over the world, the question of identity, and in particular digital identity, is at the heart of the issues at stake in our contemporary societies, which are being digitized at breakneck speed.

According to the United Nations, "73% of the world's children under the age of 5 have had their births registered, but only 46% of those living in sub-Saharan Africa".[2]

1 This theme is the subject of a dedicated chapter "Government & Public Services".
2 "Goal 16: Promote just, peaceful and inclusive societies", United Nations, SDG website, retrieved May 9 2022, https://www.un.org/sustainabledevelopment/peace-justice/

Of a world population of 7.9 billion people,[3] one billion people cannot prove their identity, which the World Bank[4] says is critical to at least ten of the Sustainable Development Goals.

As we wrote in 2020, "*without identity, there is no ownership of land, houses or agricultural land; without identity, there is no bank account, so no trade or credit, and no development aid without intermediaries. Without identity, there is little or no access to health care, except for emergency care provided during disasters. Without identity, children cannot go to school. Without identity, there is no voting and no access to justice*". Target 9 of Sustainable Development Goal 16 specifically calls for ensuring "*legal identity for all people by 2030, including through birth registration*".

Moreover, in developed countries, identity, now digital, has become the essence of "surveillance capitalism",[5] a notion popularized in 2014 by American economist Shoshana Zuboff, professor emeritus at Harvard Business School. The industrial capitalism of the 20th century, led by the car manufacturer Ford, is being succeeded by another form of capitalism, data capitalism, optimized by Google in the 2000s. Surveillance capitalism bases its model on the systematic recording of all the personal data of individuals and their interactions, most of the time without their knowledge, analyzed with the help of powerful software (big data and artificial intelligence) in order to sell a prediction of future behavior to online advertisers.

The problem is twofold. On one hand, some countries characterized by institutional failure are unable to provide their citizens with a means of proving their identity, and on the other hand, in developed countries, individuals benefit from a very relative anonymity, whether for commercial and financial reasons (surveillance capitalism), or for political and security reasons (the fight against terrorism and money laundering).

In developing countries, identity is all the more crucial as it is the first vector of legal recognition from which a person can claim ownership of a piece of land and access a multitude of services, notably public (including access to justice, social security, the right to education, the right to vote, etc.) or private (financial services).

3 According to the World Economic Forum, the latest data shows there are just over 987 million people in the world who have no legal identity, down from 1.5 billion in 2016. The majority live in low-income countries where almost 45% of women and 28% of men lack a legal ID. Source: "A billion people have no legal identity - but a new app plans to change that ", Nov 20, 2020, https://www.weforum.org/agenda/2020/11/legal-identity-id-app-aid-tech/

4 "ID4D. Country Diagnostic : Kenya", World Bank, World Bank website, 2016, retrieved May 9 2022, https://documents1.worldbank.org/curated/en/575001469771718036/pdf/Kenya-ID4D-Diagnostic-WebV42018.pdf

5 "Capitalisme de surveillance", Françoise Laugée, *La revue européenne des médias et du numérique* N°50-51 Printemps - été 2019, https://la-rem.eu/2019/07/capitalisme-de-surveillance/ et "Encore une autre approche du capitalisme de surveillance", Christophe Masutti, *La revue européenne des médias et du numérique,* N°59 Automne 2021, https://la-rem.eu/2022/01/capitalisme_de_surveillance/

What is the interest of using public blockchains in the fields of digital identity, on a personal or professional register?

What are the issues involved in blockchain projects related to land ownership, land registry or document certification?

Decentralized Identity

Digital identity is "*the ability to securely use the attributes of one's identity to access a set of resources*".[6]

The contribution of blockchains in the field of digital identity is to **reverse the current model based on authentication and access control managed by an organization, to a model based on the verifiability of certificates controlled by a person**.

This means moving from a centralized model where the user creates a login and password and disseminates his personal information to each service, to a decentralized model where the user remains in control of his personal data.

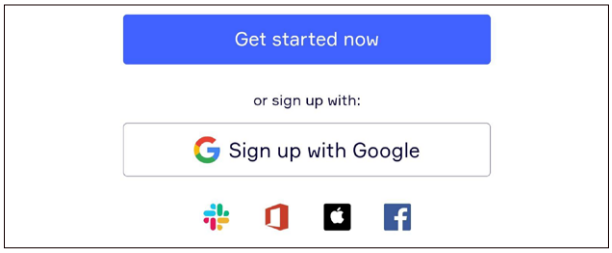
This also solves many security problems linked to the centralization of data in a single point, which is subject to recurrent hacking.

A decentralized model allows a person to provide proof of his identity or one of its facets, such as his age, to the service he wishes to access.

This paradigm shift in digital identity marks a turning point for large web companies that have based their business model on the massive and centralized exploitation of personal data without their users' knowledge, in particular for a federated identity provider, a Facebook or Google

6 French Parliament, Mission d'information commune sur l'identité numérique, Rapport N° 3190, Mme Christine HENNION et M. Jean-Michel MIS, Rapporteurs, 8 juillet 2020, https://www.assemblee-nationale.fr/dyn/15/rapports/micnum/l15b3190_rapport-information

account, serving as an identification solution for third party services (see image).



The promise of decentralized identity is to allow the user to prove something without revealing any personal information. For Thibault Langlois-Berthelot, a doctoral student in law at EHESS, "*a decentralized identity model proposes that the user regain control over his own identity by creating one or more unique identifiers called '***decentralized identifiers***', with which he will associate his verifiable credentials*".[7]

These decentralized identifiers are computer standards that define new data exchange mechanisms based on cryptography and distributed registries. These open source and public standards are being developed worldwide, notably by the W3C, Trust Over Ip[8] affiliated with the Linux Foundation, and the Decentralized Identity Foundation.[9]

From a decentralized identifier stored in an identity wallet*,[10] a person proves, through "verifiable attestations" that they select: what they know (diplomas, authorization to practice a trade, certification); what they have (bank account, citizenship); what they own (land, residence, property, vehicle); who they are (height, weight, age); what they do (job, past or present); where they have been (participation in an event); whether or not they have been vaccinated against Covid 19 etc.[11].

These verifiable credentials are "*standardized digital certificates that facilitate the exchange and sharing of information online, in a sovereign and secure manner*". [12]

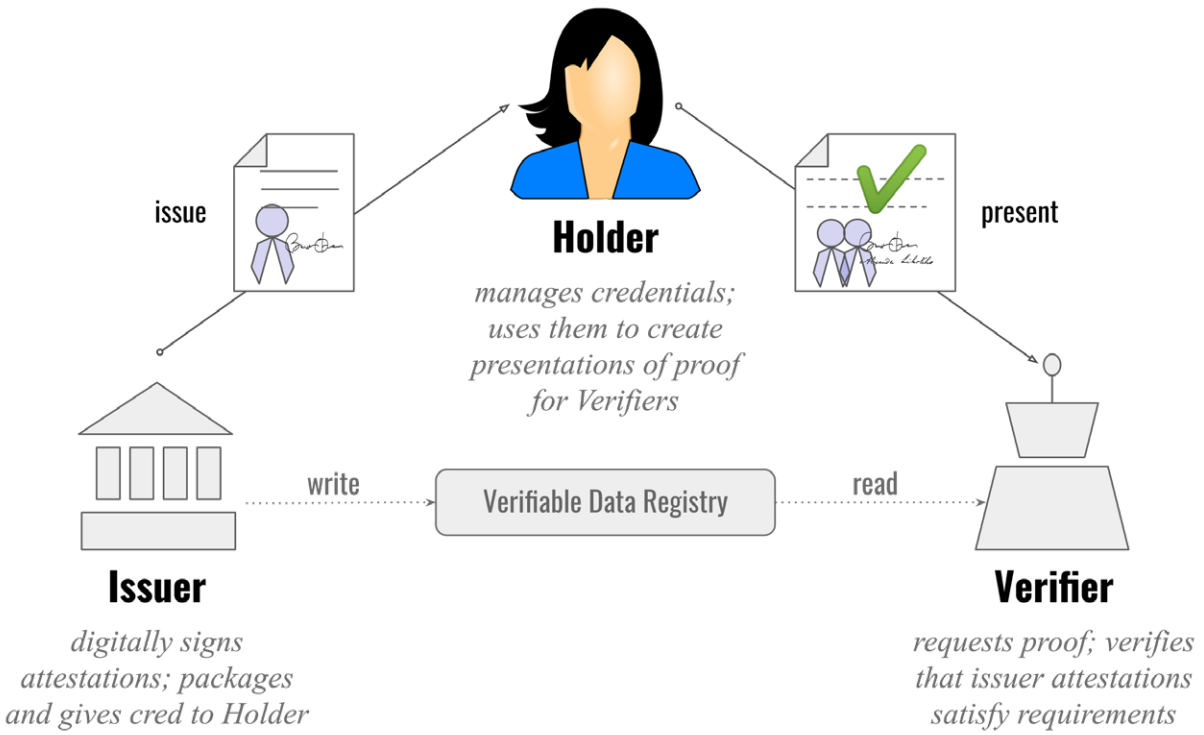
A decentralized identity system involves three entities:

1. an issuer issues a decentralized identifier (DID) to a holder,

2. on the basis of this identifier, the holder presents verifiable credentials to a verifier, for example to access a service, and

3. the verifier verifies these credentials.

7 "Blockchain et souveraineté, les prémices d'une révolution de l'identité numérique", Thibault Langlois Berthelot, 27 octobre 2021, https://hal.archives-ouvertes.fr/hal-03314568
8 "About us", Trust Over IP Foundation, Trust Over IP Foundation website, retrieved May 9 2022, https://trustoverip.org/about/about/
9 "Our Focus", Decentralized Identity Foundation, DIF website, retrieved May 9 2022, https://identity.foundation/
Words marked with an asterisk are included in the glossary at the end of the report.
11 "An Introduction to Verifiable Credentials", Verifiable Credentials.io, retrieved May 9 2022, https://verifiablecredential.io/learn
12 Op. Cit. "Blockchain et souveraineté, les prémices d'une révolution de l'identité numérique", Thibault Langlois Berthelot, https://hal.archives-ouvertes.fr/hal-03314568



Verifiable credentials, triangle of trust
Source: *Credentials, triangle of Trust* , Daniel H Hardman - CC BY-SA 4.0.
https://upload.wikimedia.org/wikipedia/commons/thumb/5/51/VC_triangle_of_Trust.svg/2560px-VC_triangle_of_Trust.svg.png

- The holder is an entity, such as a student, a person, or an employee, who acquires and keeps one or more decentralized credentials, depending on their needs and the services they want to access.

- The issuer is an entity, such as a company, an NGO, a government, or a university, that certifies some fields of this identity: name, age, country of birth, bank assets, etc. These fields are not necessarily all present in a single DID, and a person can have several DIDs. For example, a civil DID may encode a person's marital status, while a banking DID could encode information about an account number.

Based on a DID, a DID holder can produce a verifiable credential, which is a statement of fact about one or more of the fields in the DID, which remain secret. For example, on the basis of the civil DID, a proof of majority can be provided without revealing one's age. On the basis of the banking DID, solvency can be proven without revealing one's name or the amount in one's bank account. This is possible thanks

to the Zero-Knowledge Proof protocol.[13]

- Finally, the verifier is an entity, such as an employer, law enforcement, or department, that receives a verifiable statement and verifies it using the Zero-Knowledge Proof verification technique.

In practice a DID can be seen as a link that points to a complete document containing the cryptographically protected DID fields. This document is stored in a verifiable data registry that can admit various degrees of centralization depending on whether it is placed in a blockchain or other types of databases.
This verifiable data registry serves as an indirect intermediary between the issuer of a verifiable certificate and the verifier. The holder thus controls the information they choose to share in the form of verifiable attestations and can attest to all or part of their identity attributes without the issuer being informed.

Instead of filling in their name, creating a login, a password and delivering personal information to any service, the holder of an identity wallet* has verifiable credentials from which the service to which they wish to prove something verifies that what they claim is true. This new paradigm of decentralized identity relies crucially on a technical framework that allows the implementation of the principle of "Zero-Knowledge Proof" proposed by Charles Rackoff, Shafi Goldwasser and Silvio Micali in 1985.[14]

Zero-Knowledge Proof allows evidence of facts about personal data to be presented without revealing the personal data. "*These proofs do not reveal any information other than the fact that these properties or statements are true*" explains Daniel Augot, Director of Research at INRIA and professor at the École Polytechnique.

This technology is natively deployed on some public blockchains such as **ZCash** or **Monero**, but can also be deployed on top of existing blockchains such as **zk.money** on **Ethereum**. It offers a wide variety of uses, notably in the field of finance, health or decentralized identity, and the common denominator is the confidentiality of data.

This decentralized identity model solves the problems of centralization of personal data of individuals by each entity with which they interact, by offering a paradigm where the individual regains control over their identity, and by guaranteeing both the confidentiality of their data and transparency with the entities with which they interact. For example, humanitarian organizations collect the personal data of aid beneficiaries in huge independent and often redundant databases such as the World Food Program's (WFP) SCOPE, which contains 20 million identifiers,

13 In a very similar, but different context, this Zero-Knowledge Proof technology is for example deployed in the France Identity application, https://france-identite.gouv.fr
14 "The knowledge complexity of interactive proof-systems", Shafi Goldwasser, Silvio Micali et Charrles Rackoff, Symposium of the Theory of Computation (STOC),1985.

the International Organization for Migration's (IOM) personal identification and registration system, which also contains 20 million identifiers, or World Vision's mobile Last Mile solution, which contains 8 million identifiers.[15]

In April 2021, the Ethiopian government signed an agreement to implement a decentralized digital identity solution for all 5 million students in the country's 3,500 schools.[16] 750,000 teachers will also have access to the system. The goal is to provide a decentralized digital identity to students and to develop the country's education system, which is part of the country's digital transformation strategy, Digital Ethiopia 2025.[17]

According to the Minister of National Education, the government has also reached an agreement with a Chinese manufacturer of tablet computers, which will be distributed to students. [18]. The program, which is under development, uses Atala Prism[19] based on the Cardano public blockchain, a "decentralized identity solution that allows people to own their personal data and interact with organizations in a transparent, private and secure manner".

FlexID Technologies is a startup based in Harare, Zimbabwe, founded in 2018 by Victor Mapunga, originally from Zimbabwe, and Haardik, originally from India. They met at Yale University and then followed on at King's College London. In early 2018, Victor wanted to open a bank account in Zimbabwe. "I was shocked to see a long form to fill out, which required very unrealistic information, especially in a country like Zimbabwe that has a 90% unemployment rate, which means most people live in the 'informal' economy". Among the documents requested are a salary slip or proof of residence, documents that the majority of Zimbabweans are completely unable to provide. It is with this in mind, especially the fact that the impossibility of opening a bank account depends largely on the absence of identity documents, that FlexFinTx was created a few weeks later. [20]

FlexFinTx is a self-sovereign decentralized identity platform built on the Algorand public blockchain and paired with the FlexID Wallet identity wallet. A user creates a FlexID for free using a USSD code (generated from their cell phone) or via WhatsApp.

15 Organisation internationale pour les migrations, consulté le 9 juin 2022, https://www.iom.int/fr
16 "Ethiopia's blockchain deal is a watershed moment – for the technology, and for Africa", Iwa Salami, May 20, 2021, https://theconversation.com/ethiopias-blockchain-deal-is-a-watershed-moment-for-the-technology-and-for-africa-160719
17 "A digital roadmap for the developing world", Blavatnik School of Government, Blavatnik School of Government website, June 24, 2020, https://www.bsg.ox.ac.uk/news/digital-roadmap-developing-world
18 "Ethiopian Education Minister Confirms Cardano Blockchain Partnership", Anna Baydakova & Marc Hochstein, coindesk.com, April 30, 2021, https://www.coindesk.com/business/2021/04/30/ethiopian-education-minister-confirms-cardano-blockchain-partnership/
19 "Powering the Trust Economy", Atala Prism, website, retrieved May 9, 2022. https://atalaprism.io/app
20 "How FlexID is using Algorand to tackle a $50B problem across Africa", Haardik, January 28, 2020,

The user's digital identity is stored on the Interplanetary File System (IPFS)*, a distributed file storage system (see "Web 3.0, Arts & Sciences chapter), written to the public blockchain so that only the user holds the private key.

From an application on their phone, or through a physical identity wallet, users are able to prove their identity and thus access a range of services including "*creating a bank account, applying for a loan or even renewing their driver's license without having to go to a physical branch*".[21]

The FlexFinTx platform is built on the standards established by the World Wide Web Consortium (W3C) for decentralized identities and verifiable credentials, ensuring interoperability with other service providers. According to Mapunga, "*the platform is extremely inexpensive for businesses and governments to implement. In Africa, companies and governments would have to spend millions of dollars to develop such systems, sometimes through corrupt bidding processes and built by foreign companies that have no knowledge of the African market*".[22]

The solution was awarded World Economic Forum Tech Pioneer in 2021, where Zimbabwe was represented for the first time.

Land and Titling

Access to land, proof of identity and the enforceability of a property title are fundamental to the inclusion of people in society. Indeed, for the most disadvantaged, land assets are often the only way to access financial services and to prove their identity.

In countries where there is no land registry, the interest in using a blockchain lies in the immutability of the registry and the ease with which it can be interrogated. In addition, geolocation tools facilitate the identification and marking of unregistered land.

With a digitized cadastre, the dematerialization of land titles also solves the problem of loss of paper documents, especially in case of natural disasters or conflicts. Finally, the absence of a centralized body in charge of registering and maintaining the registry provides a response to the problem of corruption in certain parts of the administration, particularly arbitrary expropriations or appropriations.

Target 4 of Sustainable Development Goal 1 aims to ensure that "*by 2030, all women and men, particularly the poor and vulnerable, have equal rights to economic resources and access to basic services, land ownership, control over land and other property, inheritance,*

https://medium.com/flexfintx/how-flexid-is-using-algorand-to-tackle-a-50b-problem-across-africa-daa5916b07b3
21 *Ibid.*
22 *Ibid.*

natural resources and appropriate technology and financial services, including microfinance".[23]

In addition, access to property and security of tenure are directly relevant to Sustainable Development Goal 5, gender equality, with reforms aiming to give women the same rights as men, especially since they represent the largest share of the agricultural workforce in Africa; and Goal 8, which aims to "*promote sustained, shared and sustainable economic growth, full and productive employment and decent work for all*".

Ghana, Bangladesh, Afghanistan, India, Sweden and Georgia are some of the countries that are taking a close interest in blockchain technologies to set up a decentralized land registry. As we detailed last year in our previous report[24], Georgia, through the National Public Registry Agency, has secured over 2 million land titles in the Bitcoin blockchain[25].

Created in 2015 by Emmanuel Buetey Noah, BenBen is a private company based in Ghana that aims to *"bridge the gap between land rights holders and land market players*" by leveraging blockchain technologies. In an interview with the Technical Center for Agricultural and Rural Cooperation[26] (CTA), Emmanuel Buetey Noah explains that "*many African states still do not have a system that provides secure and reliable access to land markets*". This is mainly due to the lack of transparency and access to reliable data on land markets, a consequence of poor and overloaded public registers, as well as competition between different land tenure systems. In addition, only 20 percent of land transactions are reported to be formally concluded. As a result, 80% of land market activity is neither known nor documented[27].

BenBen is working to aggregate data on both formal and informal public transactions in order to address the challenges of land acquisition in Ghana, which is "*plagued by multiple sales, numerous unofficial fees, unnecessary bureaucracies, intrusion by unqualified intermediaries, and lack of transparency, among others*".[28]

BenBen's data aggregation work results in a set of land data that can be used by different market players. To improve access to this data, the current version of BenBen's solution also offers features to facilitate the application and registration of secured land transactions by different participants in the Ghanaian land market.

23 Target 1.1: By 2030, eradicate extreme poverty worldwide.
24 "Blockchain et développement durable", Blockchain for Good, https://blockchainforgood.fr, juin 2020.
25 Using Bitfury's open source Exonum Framework, https://github.com/exonum
26 CTA is a joint institution operating under the Cotonou Agreement between the ACP (African, Caribbean and Pacific) Group of States and the EU (European Union) Member States. CTA is funded by the European Union.
27 BenBen Ghana : autonomiser les citoyens grâce à la sécurité foncière", Jacelyn Bolt, CTA Blog, 06/11/2019, https://www.cta.int/fr/blog.
28 *Ibid.*

BenBen's technical architecture is based on the use of a distributed registry to ensure the integrity and immutability of land ownership data in order to both simplify administrative procedures and offer this service at affordable costs.

The prototype described by BenBen would leverage the public Bitcoin blockchain[29] and the Interplanetary File System (IPFS)*, hashing data related to transactions and anchoring it in the Bitcoin blockchain, thus "*keeping an immutable and publicly accessible record of blocks that link to various documents and land transactions performed via the platform. In addition, the storage capabilities of IPFS allow us to provide a secure data sharing protocol, store immutable cadastral data (related to land ownership), and prevent duplication of land transaction records and documents*".

In Afghanistan, the United Nations Office of Information and Communications Technology (OICT), in partnership with UN Habitat, [30] has been testing a digital land registry based on a distributed registry since 2019: **goLandRegistry**[31] for "government office Land Registry". Based on the observation that "*80% of urban properties are not registered with local or national authorities*" and that land ownership issues are "*at the root of armed conflicts and human rights abuses*", the organizations are developing a "*system designed to register all property documents on a blockchain, as well as to issue certificates of occupancy*", which will allow owners to independently demonstrate the authenticity of certificates of occupancy using an open source and universally accessible verification tool.

goLandRegistry is built on the LTO Network hybrid blockchain, which is built on both a public and private network. Organizations privately record transactions between themselves in order to temporally order events such as contract signatures. Some of this information is then anchored on a public blockchain, which makes it possible to record on the public chain what they have done between them. The two United Nations organizations have developed a computer system to record and verify land registry documents and to track land financing from foreign countries[32].

According to the United Nations, the goLandRegistry program contributes to Sustainable Development Goals 1, 5, 11, 13, 15, 16 and 17[33] and would have been

29 "BenBen Ghana : autonomiser les citoyens grâce à la sécurité foncière", Jacelyn Bolt, CTA Blog, 06/11/2019, https://www.cta.int/fr/blog.
30 Specialized agency of the United Nations (UN), created in 1978 and headquartered in Nairobi, Kenya, whose goal is to promote sustainable development cities to provide shelter for all.
31 "What is goLandRegistry ?", OICT, OICT website, retrieved May 9 2022, https://unite.un.org/goLandRegistry/home.
32 "Blockchain Land Registry Launches In Afghanistan Through UN And LTO Network Partnership", https://news.yahoo.com/blockchain-land-registry-launches-afghanistan-182913439.html.
33 "What is goLandRegistry ?", OICT, OICT website, retrieved May 9 2022, https://unite.un.org/goLandRegistry/

extended to other countries. Since the Taliban came back to power in September 2021, we don't know what will happen to this UN program.

> Based in Amsterdam, LTO Network has developed a platform that records between 80 and 100,000 transactions per day and is now used by the Dutch government, the Afghan government, Heineken, the United Nations, Airbus, Bosch, Dekkra and IBM. LTO deploys a hybrid blockchain system, combining the use of a public blockchain whose consensus mechanism is based on proof of stake and private blockchains, controlled by organizations, which operate their own consensus mechanism based on a hashed version of transactions recorded on the public blockchain.

In Bangladesh, Digiland, established in 2018, is focused on "*digitizing the land registry system by developing a transparent and immutable property platform based on blockchain technology*".

The stakes are high as Bangladesh is one of the most densely populated states in the world, with 165 million people in an area as small as New York State, and 22 million in Dhaka alone.

"*Since 2018, Digiland has been working with the Bangladeshi government to set up a property registry on the same model as the one developed in Georgia*[34]*, i.e. interfacing the system with the administration and the government so that property titles are recognized and therefore enforceable against everyone*[35]", explains Niklas Friese, one of its founders.

Among the difficulties encountered by Digiland is the fact that few Bangladeshis have an identity document. In addition, the rules of inheritance and transmission of land are largely dependent on religion, and some land, especially land managed by agricultural cooperatives, is administered by a village headman rather than by the farmers.

The property registry consists of registering property titles in both the public Ethereum blockchain and a private sidechain*.[36]

home.

34 "Blockchain et développement durable", Blockchain for Good, June 2020, https://blockchainforgood.fr

35 Phone interview, December 8, 2022 - Blockchain for Good

36 Digiland Public Registry: https://www.digiland-chain.com/instructions Retrieved May 20, 2022.

Certification and Notarization

Beyond digital identity and land registry, it is useful to be able to prove at a specific time the authenticity and existence of documents such as a contract, a diploma, a lease, a photo, a legal act etc. Until now, this process has always required the intervention of a public officer or a third-party authority certifying the existence and date of a document.

When the document is certified by a public officer, it is an authenticated instrument, i.e. enforceable against all. An authenticated instrument is "*one that has been received by public officers having the right to act in the place where the instrument was drawn up, and with the required solemnities*".[37] These public officers have the role of third party certifier in the eyes of the law and of everyone. In France, for instance, such public officers are notaries, bailiffs, auctioneers or clerks of the commercial courts, etc.

When two companies sign a contract, for example a confidentiality agreement, they can plan to certify the document in order to anticipate future disputes. If it turns out that one of the parties is passing on information to a third party, he or she could claim to have done so before signing the agreement. The date of signature, the integrity of the document and the signature of the contract are therefore of crucial importance.

To certify the confidentiality agreement, the parties could rely on a trusted third party whose purpose is to provide this certified time-stamping service, also known as a "Timestamping Authority" (TSA).

Trusted timestamping is a system that allows keeping the proof of the existence of a document and its content at a precise date and that implies that once the document is dated and signed, it is impossible for anyone, even its owner, to modify it.

Going through a trusted third party has a cost; so does being a trusted third party. For example, a degree-granting university or school must maintain a registry of graduates, and be able to be contacted by companies and organizations that want to verify that a person has actually graduated from the school or university in question.

Registering the fingerprint of a degree in a public blockchain can greatly simplify the process of verifying the authenticity of a degree.

We will discuss this issue in the chapter "Education and Employment".

37 Article 1369 of the French Civil Code, https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000032042446/#:~:text=L'acte%20authentique%20est%20celui,décret%20en%20Conseil%20d'État.

Hash a text using the SHA-256 algorithm

SHA-256 is a hash standard that allows to match any binary data with a unique 64-character hexadecimal hash. A hash function is a mathematical function that transforms any content into a hexadecimal number. The slightest change in the content causes the hashed number to become completely different.

Let's take the following example. If we hash the text "Blockchain and sustainable development", the result of the hash will be as follows:
faf60b6b9dc3561f167f9b88ab2c8229bb883da79afe4f11b22be7dda692618c.
If we modify the hash text by removing the emphasis on the word development "Blockchain and sustainable development", the hash result will be as follows:
0214a2148333104bf8ff3e8108bee1944b9a614727f4871ec6473b5d5f43fd38.
It is therefore impossible to find the original message from the hash. On the other hand, if we hash again " " Blockchain and sustainable development ", we will always find the same hashed number :
faf60b6b9dc3561f167f9b88ab2c8229bb883da79afe4f11b22be7dda692618c, proving that the text has not been modified.

It is possible to hash a sentence, a password, or even The Iliad and The Odyssey in extenso which is more than 700 pages long, this will always give a unique fingerprint of 64 hexadecimal characters. The interest of a hash function is that it applies only in one direction: the hashed number obtained does not make it possible to go back to the original content, on the other hand it is enough to hash this content again to check that the resulting hash is identical, proof that no modification has occurred.

Public blockchains such as Bitcoin, Ethereum or Tezos are universal registers, open and accessible to all, and whose data is immutable. Document certification services have been created based on these public blockchains, including Woleet, KeeeX, OriginStamp and OpenTimestamps. Woleet is a "*platform that guarantees the integrity and provenance of data by linking any type of digital content to immutable Bitcoin transactions*".[38] It is not the document itself that is recorded in a public blockchain but the hash of the document. Documents certified in this way can be verified without a third party, anywhere in the world and at any time.

In France, the Caisse des dépôts et consignations, La Poste, Engie and EDF have created Archipels, which offers, according to its CEO Hervé Bonazzi,

38 "Woleet : Fournisseur d'accès à la vérité numérique", Vincent Barat, Gilles Cadignan, Livre blanc, 30 Juin 2017, https://www.woleet.io/wp-content/uploads/2019/06/Woleet-WP-0.3-FR.pdf

"*a sovereign infrastructure that can manage and verify digital identity. It is a digital trust platform that certifies documents, data and information about individuals or companies on the blockchain and makes their authenticity verifiable*".[39] Developed with Vialink,[40] Archipels, a French actor in the automation of customer file processing (Know Your Customer) for banking, insurance and real estate, launched in early 2021 an initial service to check the authenticity of proof of address, for which fraud attempts are constantly increasing[41].

"*Our solution aims to create a global trust infrastructure available to any third party wishing to verify the authenticity of a document. Our blockchain is private and permissioned, which means that the actors validating transactions are identified and authorized by trusted third parties. We have total control over the origin of certified documents*"[42] explains Hervé Bonazzi.

As the blockchain is private and permissioned, it relies on a consensus algorithm based on Proof of Authority*, in which a few partners are in charge of validating transactions and updating the distributed ledger among themselves.[43]

Archipels' customers are banks, clerks of the commercial courts or regulated professions that have the obligation to verify proof of address.

In November 2021, Archipels recorded 40 million of these documents, guaranteeing their authenticity to their customers. The documentary certification proposed to the National Council of Commercial Court Clerks will allow clerks, in 2022, to verify, *via* an API*, the existence of the headquarters of companies registered in the Commercial and Companies Register (RCS).

The advantage of using a private, permissioned blockchain is to gain auditability between a few trusted partners and optimize the costs associated with their coordination.

The Paris Chamber of Notaries developed an initial pilot for document certification and timestamping in 2019, on the open source Hyperledger Fabric platform. Since July 2020, the Paris Chamber of Notaries has been developing a distributed registry, alongside Espace Notarial, the traditional business software already used by the profession, whose purpose is to dematerialize files, exchanges and signatures with their clients and each other.

39 Archipels, https://www.archipels.io
40 "Who we are ?", Vialink, consulted may 9, 2022, https://www.vialink.fr/fr/qui-sommes-nous/lentreprise-vialink-qui-sommes-nous-2/
41 "Onfido's Identity Fraud Report 2020",Onfido, https://onfido.com/landing/fraud-report-2020/
42 "La blockchain pour certifier des documents personnels", Philippe Richard, 4 mars 2021, https://www.techniques-ingenieur.fr/actualite/articles/la-blockchain-pour-certifier-des-documents-personnels-90033/
43 "Notre Manifeste", Archipels, consulté le 9 mai 2022, https://en.archipels.io/notre-manifeste

The blockchain, private and with authorization, will be used, among other things, to exchange very large files, track and certify electronic documents and track the shares of unlisted companies, a related application developed by the Innovation Fund of the Paris Chamber of Notaries.

Gravity, founded in 2017, is a decentralized cloud platform through which people receive, store, and share verifiable data in a secure digital wallet over which they have full control. Built on the Tezos public blockchain, Gravity is developing three types of decentralized identity-related uses: humanitarian aid solutions, government identity solutions, and lending solutions.

In particular, Gravity is participating in the DIGID project, for DIGnified IDentities, initiated in 2021 with the help of the International Federation of the Red Cross (IFRC), Innovation Norway, the Norwegian Red Cross, Save the Children Norway, the Norwegian Refugee Council and Norwegian Church Aid[44].

The project "*strives to return control and ownership of personal data to individuals, and at the same time increase collaboration between NGOs and their beneficiaries, with user consent as the key*". The Kenya Red Cross Society (KRCS) is having difficulty making money transfers to about a quarter of the beneficiaries of its aid programs. These people cannot show proof of identity, whereas the mobile money provider M-PESA, which is normally used by the Kenyan NGO, requires one to create an account.

In April 2021, the local Red Cross and RedRose[45] tested Gravity's solution with the first beneficiaries in a controlled environment, in both rural and urban areas. Anyone can benefit from a decentralized identity, including those who have neither a smartphone nor a feature phone*: the NGO fills out a profile, once, on the platform, and then gives the person a printed and then laminated QR code.

The initialfirst feedback from NGOs shows that it saves time, both for the beneficiaries and for the staff in the field. "*The time it takes to verify a beneficiary takes approximately one minute*",[46] explains an NGO that tested the solution. The system also drastically reduces financial costs by 85 to 94%, "*the cost per beneficiary of a printed and laminated QR code is 0.30 USD, compared to 2 to 5 USD for the smart card usually used by the Kenyan Red Cross*[47] [the M-PESA mobile money transfer service - Editor's note]" says Gravity.

44 "Q&A with Gravity's lead engineer: François Guérin ", Shiyao Zhang, september 23, 2021, https://medium.com/gravity-earth
45 Redrose is a UK non-profit organization established in 2014 that develops an electronic money transfer solution for the humanitarian sector. https://redrosecps.com/
46 Gravity Earth, Medium, https://medium.com/gravity-earth
47 *Ibid.*

Gravity is part of a distributed, standardized ecosystem, based on cryptography and whose operation is privacy by design[48], a world away from the usual practices of international humanitarian aid organizations, all of which currently use different identity management software, each separately based on centralized databases linked to the traditional international and local banking system or to local telecommunication operators.

The beneficiary registration process must be repeated for each new program, even within the same NGO. Gravity's proposal is to "*create a decentralized identifier that can then be used with other aid programs of the NGO and with other NGOs, which was previously unthinkable*",[49] explains Sharanya Thakur, project manager at Gravity.

The question of the interoperability of the "*decentralized identifier explorer*" proposed by Gravity haswas thus been raised. A blockchain explorer is an online software that allows visualization ofto visualize the datawritings anchored on a blockchain network. In Gravity's case, the blockchain explorer allows NGOs to verify the identity or any of the attributes of a person's identity. Gravity has ensured interoperability between different blockchains and protocols, relying on a generic, open source explorer, more open than the one initially developed in-house, and above all interoperable with the Tezos public blockchain and other decentralized identity systems. The interest for NGOs iswould be to be able to verify, from a single online tool, the decentralized identity of a person independently of the blockchain and the protocol used. For example, in July 2021, Gravity and Tykn, a humanitarian company established in Amsterdam, the Netherlands in 2016, announced[50] a collaboration to test the interoperability of their decentralized identity solutions.

They have completed a proof of concept of interoperability between Gravity's digital ID protocol built on the Tezos public blockchain and Tykn's identity wallet built on the Sovrin public blockchain as part of the DIGID (Dignified Identities in Cash Programming) project in Kenya.

Gravity is also working with the Digital Lending Association in Kenya[51] (DLAK), an association of digital lenders in Kenya. Digital lending is a lending process that is completely dematerialized and therefore

48 Privacy by design: Ann Cavoukian, former Information and Privacy Commissioner of Ontario, Canada and inventor of privacy by design, which means that privacy must be taken into account at the design stage of software, and not through regulation after the fact. *In* Ann Cavoukian, Privacy By Design. The 7 foundational principles. Privacybydesign.ca, Jan 2011, https://www.ipc.on.ca/wp-content/uploads/resources/7foundationalprinciples.pdf

49 Call with Sharanya Thakur, décembre 2021 – Association Blockchain for Good.

50 "Gravity, Tykn advancing interoperability of two decentralized identity solutions for the humanitarian sector", Charissa Ng Svenningsen, July 27, 2021, medium.com/gravity-earth/

51 "Building the Future of Digital Lending", The Digital Lenders Association of Kenya, retrieved May 9 2022, dlak.co.ke/

does not require going to a physical bank or financial institution. Growing rapidly in India but also in Africa, digital lending in Kenya alone has 49 operators[52]. The DLAK association, launched in early 2019 by eleven founding members including Tala, Alternative Circle, Stawika Capital, Zenka Finance, Okolea, Lpesa, Four Kings Investment, Kuwazo Capital and Finance Plan, now brings together some 11 million borrowers in the country. Gravity provides a decentralized identity solution to DLAK for lending applications and has deployed a data sharing platform for real-time credit underwriting.

Finally, Gravity is working with the Gaziantep Chamber of Industry in Turkey and the United Nations Development Program (UNDP) to deploy their decentralized identity solution to Syrian refugees participating in training *programs.*

The problem is that *"Hundreds of organizations provide training to 4 million Syrian refugees in Turkey. However, without central records or data sharing: 1. there is no visibility on how many beneficiaries have been reached and 2. it is impossible to provide the right training to the right person at the right time*",[53] explains Allen Walter of Tezos. The project with Gravity thus consists of providing each of the beneficiaries with "*verifiable education credentials, based on digital certificates*",[54] deployed on the decentralized identity solution.

By the end of 2021, Gravity had 3,000 people across Kenya and Turkey registered on the mainet* of the Gravity platform, i.e. having a decentralized identifier (DID see above) on their public blockchain.

52 "State of Digital Lending in Kenya - 2021", Reel Analytics Ltd, August 2021, https://www.dlak.co.ke/uploads/1/9/8/3/19835783/2021-reelanalytics-digital-lending-research-report.pdf
53 "Gravity: A Decentralized Solution To Create Trusted Private Digital Identities For Real-Life Use On Tezos", Allen Walters, April 17, 2021, https://xtz.news/latest-tezos-news/gravity-a-decentralized-solution-to-create-trusted-digital-identities-for-real-life-use/
54 *Ibid.*

ISSUES AND QUESTIONS

Decentralized digital identity is a new paradigm still under construction, first mentioned in 2012[55]. At the same time, the centralized digital identity and federated digital identity paradigms still persist, and their proponents have much to lose. Indeed, one of the major challenges in deploying a decentralized identity paradigm comes from resistance from private entities whose model relies on identifying their users, especially for advertising and commercial purposes. Rod Hall, an analyst at Goldman Sachs thus observes that currently "*digital identity does not belong to the user, but rather is provided by a myriad of websites and gatekeepers (...) Instead of logging in with Facebook, Google or Apple, a blockchain-oriented future would allow users to 'log in as themselves' without needing a third party to confirm identity*".[56]

The position of web browser vendors, Mozilla, Alphabet, or Apple is unequivocal. At the end of 2021, the W3C held a vote on whether to recommend the specification for "decentralized identifiers" DID. Since the vote within W3C was secret, the only public comments came from Tantek Çelik, in charge of Web standards at Mozilla Corporation, and also referred to comments from Microsoft and Google. Mozilla criticizes the DID specification for having "*no practical operability*"[57] which "*encourages divergence rather than convergence*" and could, in some cases, encourage data centralization. Mozilla also argues that DID's support for distributed ledger technologies such as blockchain could lead to "*energy-intensive processing that contributes to global climate change*"[58] and concludes that the standard should not become a recommendation.

55 "*First evoked by the phrase 'Sovereign Source of Authority' in 2012, decentralized identity has seen a major acceleration in its appeal and adoption since 2017*", Thibault Langlois-Berthelot. Proposal of a French taxonomy for decentralized identity. Octobre 22, 2021, https://hal.archives-ouvertes.fr/hal-03398096

56 "Ways blockchain can deactivate Facebook, Apple and Google's business models, per goldman", Tiernan Ray, The Technology Letter, December 20, 2021, https://www.thetechnologyletter.com/the-posts/ways-blockchain-can-deactivate-facebook-apple-and-googles-business-models-per-goldman

57 "Are Mozilla, Apple, Google opposing user control over identity ? | Billionaire kicks off effort to challenge social networks with "distributed" identity", Privacy Beat, September 24, 2021, https://itega.org/2021/09/24/why-mozilla-is-opposing-user-control-over-identity-billionaire-kicks-off-effort-to-challenge-social-networks-with-distributed-identity/

58 *Ibid.*

There is also the question of which entity (company, government, decentralized organization, startup...) is implementing a decentralized digital identity system. Will a self-sovereign identity provided by a state be recognized within another ecosystem and *vice versa*? Would a State recognize a sovereign identity that does not come from them? One thing is certain: to ensure this interoperability, decentralized digital identity will have to rely on standards and a common language, and the W3C plays a leading role in this respect[59].

It turns out that implementing a decentralized identity solution at the government level depends largely on the maturity of the country's public services: it is much simpler for a country that does not have an identity system to gradually switch to a decentralized identity model, and more complex to consider for a country that relies on mature public services.

Another question is how to deploy a decentralized identity solution in countries whose network infrastructures, internet connectivity and telephone and smartphone equipment rates are not developed, or at least leave people behind.

IN Groupe and UNICEF France are trying to answer this question by proposing DID4ALL "*a digital identity in a context of low connectivity, limited technological equipment ('feature-phone'), illiteracy and digital illiteracy*".[60]

The project aims specifically at providing an identity to the 166 million children in the world who do not have a legal existence in their country. The objective of DID4ALL is to combine a voice recognition technology, a blockchain, and telecommunication systems by proposing a system that "*does not depend on an internet access, is accessible by all, even people who cannot read or write, is reliable, because it is based on voice identification which is a unique authentication factor and, finally, is secure since the data is stored in a distributed way and then time-stamped on a blockchain*".[61]

Decentralized identity also raises the question of how a person who loses the digital device on which his or her verifiable credentials* are stored does so. If they are stored on a cell phone and the phone is lost or destroyed, how do you recover them?

59 "Verifiable Credentials Data Model v1.1 Expressing verifiable information on the Web W3C Recommendation", November 9, 2021, https://www.w3.org/TR/vc-data-model/
60 Perrine de Coëtlogon, Marc Durand, Maxime Jeantet, Claire Génin, Romuald Ramon, et al.. Les technologies blockchain au service du secteur public. [Rapport de recherche] Université de Lille (2018-2021). ffhal-03232816v2f, https://hal.archives-ouvertes.fr/hal-03232816/document#page=50
61 *Ibid.*

With decentralized identity solutions based on "HD wallet" (hierarchical deterministic wallet), such as the one proposed by Atala Prism, a person can restore his identity wallet* by filling in a "seed phrase" generated when creating an identity wallet on a blockchain. Users must either write down this mnemonic phrase (which constitutes a risk of having their identity hacked) or memorize it by heart, at the risk of never being able to access their identity wallet* again.

In the field of decentralized land registries, particularly in Africa, how can we reconcile an individualistic, Western approach to a land registry with the culture of the country where this type of registry is set up?

This question takes on its full meaning in a context where recent major land acquisitions are generating criticism of land governance systems.

In Ghana, for example, researchers Prince Donkor Ameyaw and Walter Timo de Vries of the Technische Universität München in Germany explain that "*the overriding principle for all these categories of customary land is that the land is collectively owned by the members of the communities, but the management of the land (and decisions about its allocation and use) are made by the customary authorities on behalf of their members. According to some traditions in Ghana, land is managed by customary leaders on behalf of past, present and future community members*".[62]

The question of how to reconcile customary law with a distributed registry remains.

62 Ameyaw,P.D.;deVries, W.T. Toward Smart Land Management: Land Acquisition and the Associated Challenges in Ghana. A Look into a Blockchain Digital Land Registry for Prospects. Land 2021, 10, 239. https://doi.org/10.3390/land10030239

PEER-TO-PEER ELECTRONIC CASH SYSTEM & PROGRAMMABLE MONEY

PEER-TO-PEER ELECTRONIC CASH SYSTEM & PROGRAMMABLE MONEY

Number of projects in the directory: 235

Number of active projects: 141

Name of active projects: 0x ; AAVE ; Abra ; Acre Africa micro-insurance ; Adhara ; Airfox ; Akoin ; Akropolis ; Algorand ; Arbol ; Arcadia Blockchain Technologies ; B Protocol ; Bazaar Tech ; Bisq ; Bit Sika ; Bitpesa ; Bitt ; Bloom ; Botkeji (Kaoun) ; Bottlepay ; Cambiatus ; Cellulant ; CELO ; CentBee ; Centrifuge ; Chia ; Chynge ; Circles ; ClickPesa ; Coinify ; Coins.ph ; Colendi ; Compound ; Compound Labs ; Crowdforce ; Crypto Development Fund (CDF) ; Curve ; DEMARS ; Dether ; dGE - Diggi ; Dharma ; Diem (ex Libra) ; Digital Citizen Fund ; DistributedTown ; Dorium ; Eco Coin ; EcoChain ; efforce ; Ejara ; Etherisc ; Ethic Hub ; Evercity ; Everex ; Experty.io ; FintruX ; Flutterwave ; Freecoin ; FutureThinkers NFT ; Galoy ; Gooddollar ; Grassroots Economics ; Hive online ; Humaniq ; IcrowdU ; Impact Cred ; Inclusivity.network ; Insurwave ; Invictus Capital ; IOHK ; ixo foundation ; KamPay ; Kin ; Kivéclair ; Kiwi New Energy ; Korapay ; KYC-Chain ; Leman ; Local Bitcoin ; Lumoin ; MakerDAO ; M-Akiba ; Moeda ; Mojaloop ; MonedaPAR.com ; Money Track ; Muun ; Mybit ; Neco ; Nexo ; Oradian's Stellar integration ; Pancake Swap ; Parity.Tech ; Paxful ; PayCase ; Pesabase ; PledgeCamp ; Project Greshm ; Proof of Impact ; Qitmeer ; QLAY ; Raay ; Raise ; RAZ Finance ; REMIIT ; Remitano ; Retreeb ; Ricult ; Rupee Blockchain ; SALT ; Senditto ; sharehope ; Smart Valor ; SmartCredit ; SparkPoint ; Stellar ; Superfluid ; SureRemit ; Suretly ; Taro (protocol) ; Tecra ; Telcoin ; Tempo's Stellar integration ; Token Engineering Commons (TEC) ; Topl ; TrafiGuard (Bloom) ; Trustlines Network ; UCASH ; Uniswap ; Uphold ; Uulala ; VipiCash ; Vumi's Stellar Integration (Praekelt Foundation) ; Waba ; Weifund ; Women's coin ; Worldremit ; Wyre ; Xago ; Xend ; Yensesa ; Zlto ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

Bitcoin has first been described as a "peer-to-peer electronic cash system".[1] Consequently, the chapter "Peer-to-peer electronic cash system and programmable money" is the category that gathers the most projects from the positiveblockchain.io directory.

A traditional payment system is, according to the Bank for International Settlements (the so-called "central bank of the central banks[2]), a "*system consisting of a set of bancary tools and procedures as well as inter-bancary money transfers that allows the circulation of a currency*".

A peer-to-peer cash system works differently: it is a peer-to-peer network protocol that usesasymmetric cryptography and a consensus mechanism to maintain a ledger compiling all users' crypto-currency transactions, without any financial intermediary.

As Satoshi Nakamoto wrote before disappearing[3], "*the root problem with conventional currency is all the trust that's required to make it work. The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust. Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve*".[4]

Among the projects identified in the database, many are in line with the Decentralized Finance (DeFi) movement initiated in 2018. Some, like Clément Jeanneau from **Blockchain Partner**, use to call this movement Open Finance, in order to highlight that opening financial services is a mean and not the goal *per se*.

DeFi allows anyone who has the financial means, regardless of nationality or country, to borrow, lend and invest on the side of insurance and exchange crypto-assets without any intermediary, transactions being secured by the combined use of a blockchain and smart contracts* . Nowadays, financial institutions exclude the entire part of global population who does not have access to legal identity[5] (see chapter "Identity and Ownership"). According to the 2021 World Bank Global Findex, 1.4 billion of the global population does not have a bank account[6]. **DeFi is not designed primarily for the most underprivileged people around the globe, it rather allows anyone who has the financial means to have access to financial products, regardless**

1 "Bitcoin, a peer-to-peer electronic cash system", Satoshi Nakamoto, bitcoin.org, retrieved May 10 2022, https://bitcoin.org/files/bitcoin-paper/bitcoin_fr.pdf
2 The Bank of International Settlements (BIS) is a financial international organization, created in 1930 and gathering 63 central banks in the world. Its activity is worth 95% of global GDP.
3 "The Crypto-Currency Bitcoin and its mysterious inventor", Joshua Davis, October 3, 2011, https://www.newyorker.com/magazine/2011/10/10/the-crypto-currency
4 *Ibid.*
5 See Chapter "Identity and Ownership".
6 Demirguc-Kunt, Asli; Klapper, Leora; Singer, Dorothe; Ansar, Saniya; Hess, Jake. 2018. "Base de données Global Findex 2017 : Mesurer l'inclusion financière et la révolution technico-financière". Washington, DC - World Bank. openknowledge.worldbank.org License: CC BY 3.0 IGO.

of country or nationality, even to individuals without legal identity.

These peer-to-peer electronic cash systems do not only compete with traditional currencies as mediums of exchange. As it is built with informatic code, these electronic currencies are also programmable, thanks to second generation blockchains such as Ethereum, Tezos, or, Solana. Programmed rules, called smart-contracts*[7], define when and how value is exchanged, revolutionizing the use of traditional money and inventing new financial services.

Financial inclusion brought by peer-to-peer cash systems and programmable money is at the heart of 8 out of 17 Sustainable Development Goals (SDGs): SDG 1: No Poverty, SDG 2: zero hunger, SDG 3: health and well-being, SDG 5: gender equality, especially regarding women economic empowerment, SDG 8: decent work and economic growth, SDG 9: Industry, Innovation and Innovation, SDG10: Reduced Inequalities. SDG 17 on enforced cooperation for the implementation of goals plans that financial inclusion plays a bigger role in order to drive investment and consumption to boost economic growth.[8]

As they will be detailed in this chapter, the diversity of areas of implementation of peer-to-peer cash systems is limited only by the imagination of their developers: remittances (**Bitcoin**, **Stellar**, cryptocurrency wallets), peer-to-peer payments and micro-payments (**Lightning Network**, **Taro protocol**, **Celo, Retreeb**), peer-to-peer lending and borrowing and Decentralized Finance (**MakerDAO** and **DAI**, **Compound**, **Aave**, **Uniswap**), credit scoring (**FintruX**, **TrafiGuard**), programmed money decentralized local currencies (**Leman**, **Grassroot Economics**, **Money Track**), parametric insurance (**Etherisc**, **Arbol**), basic income (**Impact Market**, **GoodDollar**), charity without intermediary (**Kiveclair**), decentralized crowdfunding (**Tecra Space**, **Raise**), financial inclusion (**Ethic Hub, Waba**, **Hive Online**), impact verification (**Ixo Foundation**, **Proof of Impact**), or even impact investment (**The Sun Exchange**).

7 Words with an asterisk are defined in the glossary.
8 Financial Inclusion and SDGs: https://www.uncdf.org/fr/financial-inclusion-and-the-sdgs

Remittances

In 2020, according to the United Nations, 200 million of women and men, most of them migrant workers, have sent 544 billion dollars to 800 million of family members[9]. **Individual remittances, often corresponding to very small amounts, represent financial flows three times more important than public development aid**.

According to the World Bank[10], in 2020, remittances officially recorded sent to low and middle income countries were worth 540 billion dollars despite the COVID 19 pandemic[11], which is only 1.6% lower than in 2019, where they reached an amount of 548 billion of dollars.

Regarding money transfers via mobile technologies, despite being less important than traditional remittances, they are worth 16 billion dollars in 2022, increasing by 48% compared to 2021.[12] However, these funds go through financial companies, which take fees on each transaction. Diminishing transaction costs correspond to the indicator 10.c.1 of SDGs, which sets a 3% fee target. On average, these fees are equivalent to 7.6% of the value of the remittance. Fees are the lowest for South-East Asia (4.9%), and the highest for Sub-Saharan Africa (8.2%).[13]

A traditional money transfer by a financial operator or a telecom operator is invoiced according to a percentage of the amount sent. It is going through intermediaries, and transactions can take days to be operated. A transaction operated on a blockchain costs only a few cents, and takes a couple of minutes to be delivered, like the ones operated by the **Stellar network**, a decentralized payment infrastructure, free to use and open source, created in 2014 by Joyce Kim and Jed McCaleb.

A protocol called **Lightning Network*** does the same thing, thanks to a bidirectional payment channel on the top of Bitcoin blockchain in order to operate micro-transactions practically feeless, by registering only two transactions on Bitcoin's main blockchain: the one that opens the channel and the one that closes it (see table p.87).

According to the World Bank, fees invoiced for traditional cash transfers represent a 16 billion dollar deficit per year for these migrant workers, in terms of savings for

9 "Remittances, a life buoy", Nations Unies, retrieved May 10 2022, https://www.un.org/fr/observances/remittances-day

10 Dilip Ratha, Eung Ju Kim, Sonia Plaza, and Ganesh Seshan. 2021. "Migration and Development Brief 34: Resilience: COVID-19 Crisis through a Migration Lens." KNOMAD-World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

11 "Defying Predictions, Remittance Flows Remain Strong During COVID-19 Crisis ", World Bank, Press Release, May 12, 2021, https://www.worldbank.org/en/news/press-release/2021/05/12/defying-predictions-remittance-flows-remain-strong-during-covid-19-crisis

"State of the Industry Report on Mobile Money 2022", GSMA. https://www.gsma.com/sotir/wp-content/uploads/2022/03/GSMA_State_of_the_Industry_2022_French.pdf

13 Dilip Ratha, Eung Ju Kim, Sonia Plaza, and Ganesh Seshan. 2021. "Migration and Development Brief 34: Resilience: COVID-19 Crisis through a Migration Lens." KNOMAD-World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

the one who sends the funds, or in terms of increased value received by earners. In El Salvador, for instance, 35% of the population receives money transfers from abroad, equivalent to 6 billion dollars in 2020, equivalent to 23% of its GDP.[14] In an interview for CNBC, El Salvador's president Nayib Bukele estimates that "*money services providers like Western Union and MoneyGram will lose $400 million a year in commissions for remittances, thanks to the country's bitcoin adoption*".[15]

Furthermore, many countries, especially in Africa, have implemented a tax on transactions via mobile phones. In Ghana, for instance, a 1.5 % tax on mobile money, known under the name of e-levy, has received a lot of criticism and "*put at threat millions of small business owners and other low-income groups, despite life cost's increase*."[16]

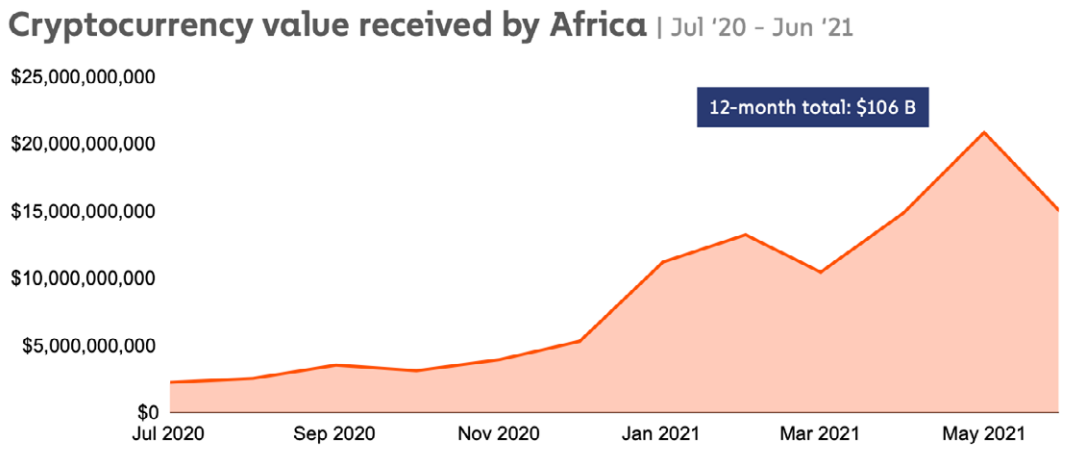
In addition to money transfers through bank intermediary or telephone operator, peer-to-peer money transfers seem to be increasingly used, especially in several emerging countries, including Kenya, Nigeria, Vietnam, and Venezuela, explains *The 2021 Geography of Cryptocurrency Report*[17] published by Chain Analysis.

According to Shubham Pandey, writer for Ambcrypto, "*restrictions on remittances [by banks Editor's note], coupled with inflation, have been the main catalysts for people to migrate to crypto-currencies*".[18] In Nigeria, for example, the use of crypto assets grew after Niger's central bank banned retail banks from facilitating transactions to crypto assets and also limited their customers' foreign remittances by $500 at a time[19].

Local Bitcoin, Paxful or **Remitano** Local Bitcoin, Paxful, or even Remitano are used to buy Bitcoins or other crypto-assets in order to transfer them without a bank, and to escape inflation and devaluation of the local currency.

Established in June 2012 in Helsinki, Finland, **LocalBitcoins**[20] allows its users to exchange their local currency for Bitcoins and offers escrow protection to ensure the safety of the crypto-assets and the two traders.

14 "Money transfer to Venezuela, Remittance Flows Amidst Evolving Foreign Exchange", Manuel Orozco Kathryn Klaas, May 2020, thedialogue.org.
15 "El Salvador's new bitcoin plan could cost money providers like Western Union and others $400 million a year, says President Bukele", MacKenzie Sigalos, September 17, 2021, https://www.cnbc.com/2021/09/09/el-salvador-bitcoin-move-could-cost-western-union-400-million-a-year.html
16 "Africa's mobile money taxes may drive the poor out of the digital economy", Kent Mensah, Nita Bhalla, June 5, 2022, https://www.news24.com/citypress/business/africas-mobile-money-taxes-may-drive-the-poor-out-of-the-digital-economy-20220605
17 "The 2021 Geography of Cryptocurrency Report" Analysis of Geographic Trends in Cryptocurrency Adoption and Usage, Oct 2021, go.chainalysis.com.
18 "'Smallest cryptocurrency economy,' Africa records 1200% hike in a year", Shubham Pandey, Sep 16, 2021, ambcrypto.com
19 Adedeji Owonibi : https://ng.linkedin.com/in/adedeji-owonibi- cited by Chainanalysis Report.
20 "About Local Bitcoin", Local Bitcoin, LocalBitcoin website, retrieved May 10 2022, https://localbitcoins.com/about



Order book trading volumes for Sub Saharan Africa from LocalBitcoins and Paxful in USD. Source : usefultulips.org - Septembre 2021.

Under pressure from the U.S. Department of Justice,[21] LocalBitcoins has stopped allowing customers to trade crypto-currencies face-to-face for cash anonymously as of 2019.

With nearly 5 million users worldwide, Paxful, founded in 2015, is a peer-to-peer exchange marketplace that allows its users to buy and sell crypto assets via some 300 payment options.

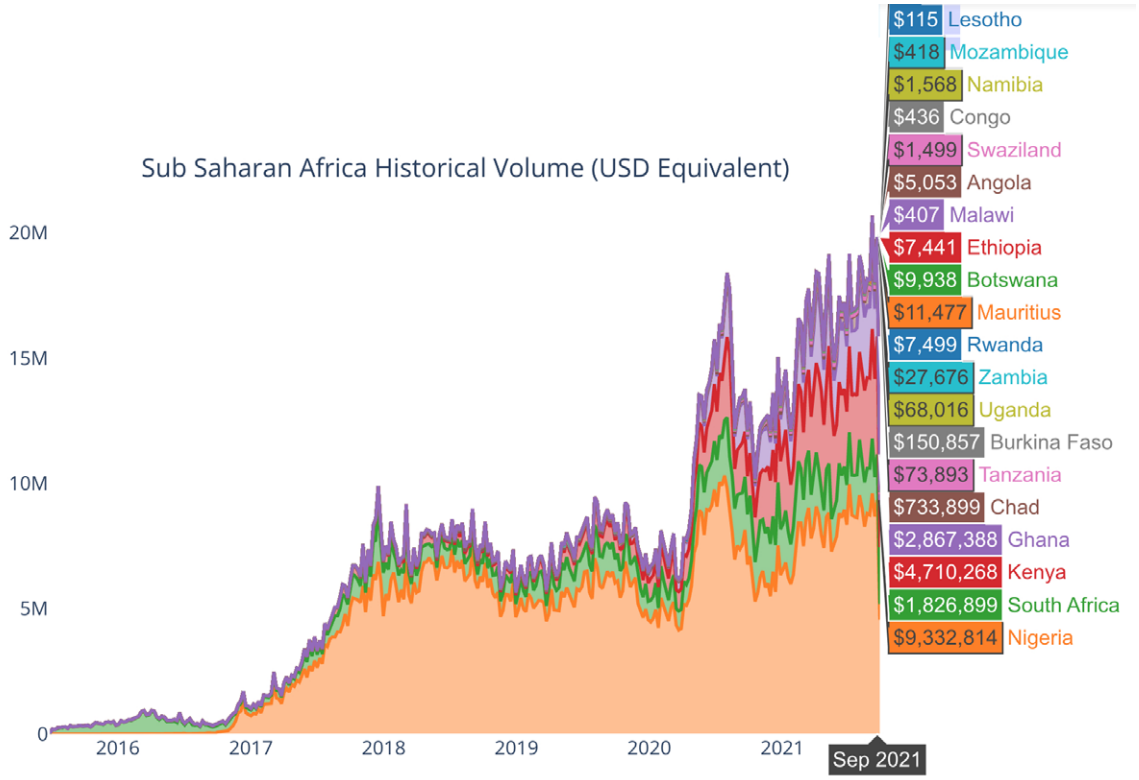
Artur Schaback, co-founder of Paxful explains that crypto assets are used in Africa to trade with foreign countries, "*If you're working with a partner in China to import goods to sell in Nigeria or Kenya, it can be difficult to send enough fiat currency to China to complete your purchases (...) It's often easier to simply buy bitcoins locally on a P2P exchange, then send them to your partner*."

Founded in 2015, Remitano is based in the Seychelles and offers a similar service to Paxful and LocalBitcoins.

Remitano is particularly well established in Vietnam, India, Cambodia, and even Nigeria.
As this chart published on usefultulip. org shows[22] the volume of transactions recorded on LocalBitcoins and Paxful in Nigeria, South Africa, Kenya, and Ghana has seen a sharp increase since the beginning of 2021.

The use of crypto-currencies to protect against inflation, however, began as early as 2013, when Cypriots bought bitcoins to preserve their savings.

21 "Local Bitcoinstops cash trades, personal offers on platform", Landon Manning, June 4, 2019, https://bitcoinmagazine.com/culture/localbitcoins-stops-cash-trades-personal-offers-on-platform
22 UsefulTulips.org is a website that explores the use cases of crypto-assets around the world. The graphs presented on the website come from the exchange data of the world's most popular peer-to-peer bitcoin exchange websites, LocalBitcoins and Paxful, https://www.usefultulips.org/about.html



Sub Shaharan Africa Historical Volume (USD Equivalent)
Source : https://www.usefultulips.org/ - retrieved September 2021.

Peer-to-peer payments and micro-payments

One of the recurring criticisms of crypto-currencies is that they are not stable means of payment due to their high volatility. However, the diversity of crypto-currencies and alternative payment system initiatives largely contradicts this preconceived notion. Not only can crypto-currencies be used as means of payment, some of which are much less expensive than centralized payment systems, but they also make it possible to build new peer-to-peer monetary services due to their programmable nature. For example, the **Bitcoin network** allows transactions to be carried out in Satoshi on a Lighting network* channel extremely quickly and at virtually no cost. The **Celo** blockchain and its stablecoins* indexed on fiat currencies allow peer-to-peer transactions with fees typically around $0.01. The development of smart contracts based on a currency like the cUSD ushers in services unimaginable with the current financial system.

Retreeb presents itself as an ethical means of payment, allocating a third of its commission to social and environmental projects. Halfway between a new payment method and a decentralized system of participatory funding, Retreeb presents itself as an alternative to centralized payment systems such as Visa, Mastercard, Stripe, or Paypal "*by placing social and*

environmental responsibility (ESG) at the heart of its business model".[23]

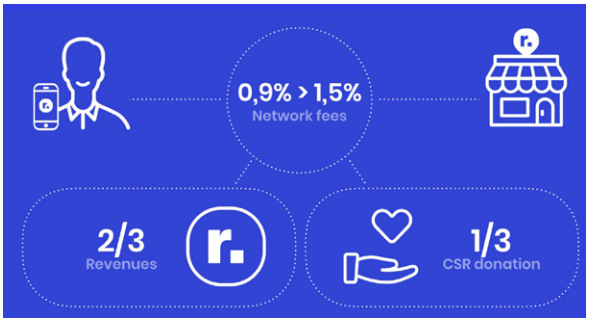
Founded in 2019 in Geneva, Switzerland, by Jérémi Lepetit and Sayah El Yatim, the company defines itself as an ethical payment method for the general public and as an answer to the question of "*how to capture the value produced by payment transactions, to better reallocate it to the societal issues of our time*"[24] explains Jérémi Lepetit.

Like any other payment method, Retreeb is aimed at the final consumer who pays a merchant using an application downloaded on his smartphone or via a biometric bank card. The payment in fiat currency is converted into a token indexed[25] to the fiat currency in a transparent way for the user (euro, Swiss franc etc.).

Jérémi Lepetit, co-founder and CEO of Retreeb explains that "*the stableTreeb is 100% collateralized by the fiat currency reserve corresponding to the deposit. The stableTreeb is minted [created] at the deposit and burnt [destroyed] after the merchant's fiat currency payment every 72 hours maximum. The stableTreeb evolves in a vacuum in our system. It is not listed anywhere. These properties guarantee its permanent 1:1 indexing. From a legal point of view, it is not a stablecoin but an on-chain* electronic currency*".

The advantage for the merchant is that the traditional commission of around 2.5 to 5%, paid to centralized payment infrastructures such as Visa or Paypal, is significantly reduced to between 0.9% and 1.5%.

The payment triggers a smart contract called "Social Smart Contract", which involves, in addition to the payer and the receiver, a third party: the Social Beneficiary representing a cause, an association, a non-governmental organization, or a project designated as a beneficiary of the social commitments, chosen by the user.



Source : https://retreeb.io/

23 Retreeb - Pitchdeck, retrieved Apr 28 2022, https://retreeb.io/assets/retreeb-pitchdeck.pdf
24 "Cette finance qui veut changer le monde", Myret Zaki, 16 novembre 2020, https://www.bilan.ch/finance/cette-nance-qui-veut-changer-le-monde
25 According to Jérémi Lepetit, co-founder of Retreeb, "The stableTreeb is 100% collateralized by the FIAT reserve corresponding to the deposit. It is mint [created] at the deposit and burn [destroyed] after the merchant's FIAT payment every 72 hours maximum. The stableTreeb evolves in a vacuum in our system. It is not listed anywhere. These properties guarantee its permanent 1:1 indexing. From a legal point of view it is not a stablecoin but an on-chain electronic currency*". Call with Blockchain for Good, June 30, 2022.

The payment protocol developed by Retreeb, Cell, is built on a fork* of the Lachesis Directed Acyclic Graph (DAG[26]) developed by the Fantom Foundation[27]. The consensus mechanism used to validate and secure transactions, Lachesis aBFT (asynchronous Byzantine Fault Tolerant), was used to reduce financial fees, to rely on a financial infrastructure capable of supporting up to 10,000 transactions per second while being interoperable with the Ethereum Virtual Machine (EVM)*, and finally, to minimize the environmental costs and carbon impact of the payment system.

Retreeb implements two tokens:

- The (s)Treeb, a stablecoin* collateralized on the user's currency and backed by a store of value strictly equal to its supply which allows the user, regardless of the fiat currency they use, not to have to worry about conversion. Thus, one sTreeb in France is equivalent to one euro, 1 sTreeb in Switzerland is equivalent to one Swiss franc, one sTreeb in England is equivalent to one pound etc. "*The system allows you to build an sTreeb per currency zone which will always have the value of the user's local currency*" explains Jérémi Lepetit.

- And the (u)Treeb or TREEB, a governance utility token used by the Retreeb community for governance purposes, notably to select supported CSR projects, and to access a premium status whose objective is to encourage long-term ownership of (u)Treeb by its users.

Celo,imagined in 2017 and launched in May 2020 in San Francisco in the United States, allows anyone with a smartphone to send and receive crypto-currencies and is particularly aimed at populations that are excluded from the traditional banking system.

Celo has long been considered the most serious competitor to the Libra crypto-currency project, which was launched by Facebook in early 2020, renamed Diem, and then finally stopped.

If Facebook's aspirations were to launch a private global currency, Celo is the equivalent, but open source[28] and accessible to all.

It is a permissionless public blockchain derived from a fork* of the Ethereum blockchain. In addition to its native token, which enables the decentralized governance of the protocol, Celo has developed three stablecoins*: the Celo Dollars (cUSD), the Celo Euro (cEUR), and the Celo Real (cREAL), each indexed to the US dollar, the euro, and the Brazilian Real. The three stablecoins had respectively made circulating, by May 2022, the equivalent of 72 million cUSDs, 37 million cEURs, and 9 million cREALS.

26 "Qu'est-ce qu'un graphe orienté acyclique (DAG) dans le domaine des crypto-actifs ?", Binance Academy, July 19, 2020, https://academy.binance.com/fr/articles/what-is-a-directed-acyclic-graph-dag-in-cryptocurrency
27 "What is Fantom ?", Fantom, retrieved May 10, 2022, https://fantom.foundation/fantom-faq/
28 Celo Gituhb: https://github.com/celo-org/celo-blockchain

Celo's promise, then, is to be "*a mobile-first blockchain that makes decentralized financial tools and services (DeFi) accessible to anyone with a cell phone.*"

The Celo wallet (and the 26 other compatible ones) not only allows its users to make and receive payments directly to people in its contact list, but also, to pay merchants who accept it, send cross-border funds for very low costs, on the side of sending, and receiving charity aid and many crypto services developed from the Celo ecosystem.

Like Ethereum, Celo is programmable through smart contracts using the Ethereum Virtual Machine (EVM). Celo, however, relies on a proof-of-stake based consensus algorithm called Practical Byzantine Fault Tolerance* (pBFT) rather than proof-of-work, thus not requiring energy consumption to validate and secure transactions. Crypto-currencies developed under Celo are Ethereum ERC-20 compliant and therefore compatible with all tools and applications in the Ethereum ecosystem.

Phone numbers are associated with addresses, numbering 2.8 million in May 2022, using a decentralized identity protocol* (see "Identity and Ownership" chapter).

The ultra-lightweight Celo client was developed to be compatible with all smartphones, including those with limited memory and connectivity. In addition, rather than storing the entirety of the blockchain's transactions on everyone's phone, Celo developed a zk-SNARK[29] based system that allows mobile nodes to synchronize with the Celo blockchain using zero-knowledge proofs* (ZKP), which allows the blockchain's synchronization computation to be quickly verified without having to be run locally and ensures data privacy.

Since its launch in May 2020, the Celo blockchain has raised $66.5 million in 8 rounds of funding[30]. Because of its compatibility with the Ethereum network, Celo is used by several hundred blockchain projects and decentralized applications around the world[31]: **Impact Market** and **GoodDollar**, which collect donations that are redistributed as basic income to disadvantaged populations, **Toucan Protocol**, **Wren** and **Moss**, which allow people to offset their carbon footprint, **Grameen**, a humanitarian aid application, and **Masa**, a decentralized credit protocol, to name just a few.

Contrary to popular belief, the Bitcoin blockchain also allows micro transactions to be carried out at near zero cost.

29 "Techniques cryptographiques visant à assurer la confidentialité des données sur une blockchain publique . Source : " Les zk-SNARKs et les zk-STARKs expliqués ", February 26, 2019, https://academy.binance.com/fr/articles/zk-snarks-and-zk-starks-explained
30 "Celo", Crunch Base, Crunch Base website, retrieved May 10 2022, https://www.crunchbase.com/organization/celo-3846
31 "Apps", Celohub, Celohub website, retrieved May 10, 2022, https://celohub.org/apps

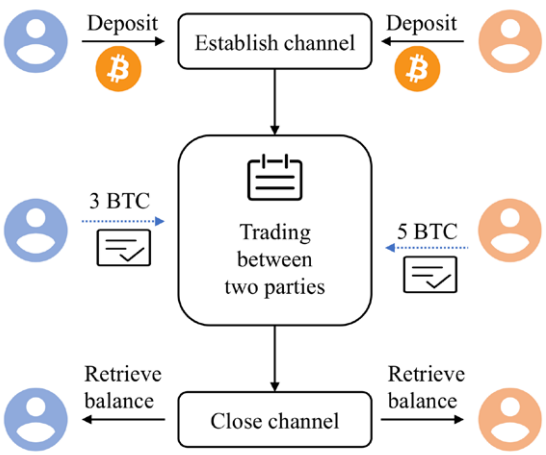


Figure 1

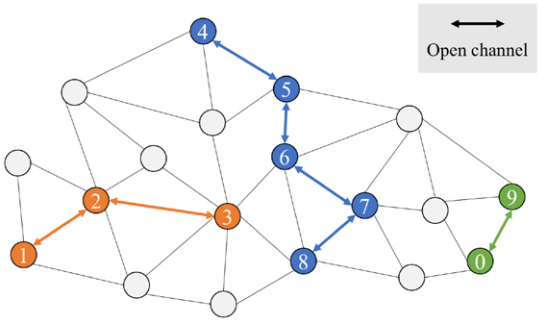


Figure 2

Lightning Network Process
Source : Zhou, Qiheng & Huang, Huawei & Zheng, Zibin. (2020). Solutions to Scalability of Blockchain: A Survey. IEEE Access. PP. 10.1109/ACCESS.2020.2967218.

The Lightning Network, a peer-to-peer payment protocol built as a second-layer application on the Bitcoin blockchain, enables extremely fast Bitcoin transactions, on the order of one million per second, at almost no cost and with no energy consumption[32], since the validation of transactions does not require proof-of-work mining*.

Since 2015, players in the Bitcoin community, including **Lightning Labs**, **Blockstream**, and **ACINQ**, have been working on this protocol, which provides one of the answers to Bitcoin's scalability problem, which, as a reminder, can only process 7 to 10 transactions per second.

The Lightning network has been operating since May 2018.

The Lightning Network white paper[33], written by Joseph Poon and Thaddeus Dryja of Lightning Labs and published on January 14, 2016, describes it as "*a network of payment channels in which each of the hosts is connected in a peer-to-peer fashion, and without recourse to a central hierarchy, forms a mesh network structure where each node can receive, send and relay transactions*."

In Figure 1, which reads from bottom to top, two people with Bitcoin wallets establish a payment channel over the Bitcoin blockchain (off-chain) by each depositing a certain amount. They can then, through this payment channel, make as many transactions as they wish (always for an amount less than the initial amount deposited), validated instantly, at fees close to zero.

32 "Comprendre le Lightning Network",Yorick de Mombynes, Institut Sapiens, 23 juin 2020, https://www.institutsapiens.fr/wp-content/uploads/2020/06/Comprendre-le-Lightning-network.pdf
33 "The Bitcoin Lightning Network: Scalable Off-Chain Instant Payments", Thaddeus Dryja & Joseph Poon,

Whenever they want, they can close the channel, which will result in the final balance of their respective accounts being recorded on the Bitcoin blockchain. Only the initial and final transactions will be recorded in the Bitcoin blockchain, and as many transactions as desired - 100, a million, or more - will be processed within the payment channel.

In addition, the Lightning network implements a payment channel network, as shown in Figure 2, to perform off-chain transactions between two parties that do not have a direct payment channel established between them but that a route connects, so that node 1 and 3 or 4 and 8 can also perform peer-to-peer transactions.

In April 2022, Lightning Labs announced the launch of the **Taro protocol**, which aims to be able to use stablecoins in applications on the Lightning network[34]. Elizabeth Stark, co-founder and CEO of Lightning Labs, explains that Taro will "*bitcoinize the dollar*". The Taro protocol allows dollar stablecoin to be converted into bitcoin, routed through the Lightning network, and then converted back from bitcoin to dollar stablecoin, which will, according to Elizabeth Stark, "*bring Bitcoin to billions of people*"[35].

The beauty of using the Lightning network is that there is virtually no limit to the number of transactions per second on the network, transactions are instantaneous from one end of the world to the other, and transaction fees are potentially less than a Satoshi (0.00000001 BTC, or $0.000039 in April 2022). As of June 1, 2022, the Lightning Network has 17,570 nodes and 85,320 channels through which 3,920 BTC, or $125 million, are circulating[36].

Kiveclair, [which we feature in the "Aid, Charity, and Philanthropy" chapter - "peer-to-peer donations"], provides an interesting use case for the Lightning Network. Started in October 2021 near the city of Goma in the eastern Democratic Republic of Congo (DRC) after the eruption of the Nyiragongo volcano, the Kiveclair project, led by a small team on the ground, with technical and logistical support from **Le Cercle du Coin**, **Indenodes**, **Nodl** and **JohnOnchain**, aims to "*help about 50 families in satoshi and train them to use Bitcoin*."

It is an online donation campaign, in satoshis or Bitcoin, which will provide people affected by the volcanic eruption with a cell phone on which a Bitcoin wallet is installed on the Lightning network, from which each person will receive a donation of about 25 USD in satoshis* twice a month for six months.

Lightning Network Website, January 14, 2016, https://lightning.network/lightning-network-paper.pdf
34 "Announcing Taro: A New Protocol for Multi-Asset Bitcoin and Lightning", Ryan Gentry, April 5, 2022, https://lightning.engineering/posts/2022-4-5-taro-launch/
35 "Number of People Go Up, or Bitcoin as the World's Protocol of Value", Elizabeth Stark, April 5, 2022, https://medium.com/@lightning_labs/number-of-people-go-up-or-bitcoin-as-the-worlds-protocol-of-value-d1df7cefca37
36 Lightning Network Search and Analysis Engine, retrieved June 1, 2022, https://1ml.com

Recipients also participate in training to learn how to use the wallet. The bitcoins/ Satoshis will not be convertible into local currency, the idea being to circulate them in the local economy through businesses also supported by Kiveclair, accepting payments in bitcoin.

According to Yorick de Mombynes, "*the number of participants, channels, and bitcoins committed to the Lightning network has been growing exponentially since the beginning of 2021* [37]" and is expected to have, according to estimates in a report published by Arcane Crypto in October 2021, 700 million users by 2030[38].

DeFi - borrow, lend, invest

Although the term DeFi, - for Decentralized Finance -was first used in August 2018 on a Telegram chat between Ethereum IT developers and entrepreneurs from **Set Protocol**, **0x** and **Dharma** , Decentralized Finance was born with **Maker DAO** created in 2014 by Danish entrepreneur Rune Christensen, a Decentralized Autonomous Organization* (DAO) based on the Ethereum public blockchain.

This new decentralized computer system addresses the first problem of the monetary system and the international financial system: its accessibility. As the French Association for the Development of Digital Assets (ADAN) notes, "*our access to financial services often depends on our social class or our geographical location. Yet, financial inclusion is synonymous with social inclusion*[39]".

According to ethereum.org website[40], Decentralized Finance (DeFi) is "*a global and open alternative to the current financial system - products that allow you to borrow, save, invest, trade, and more - based on open source technology that anyone can program with*".

To illustrate this, it is possible to take Maker DAO as an example to better grasp the challenges of Decentralized Finance.

37 "L'ingéniosité et l'inventivité du Lightning Network sont stupéfiantes", Rémy Demichelis, lesechos.fr, 25 août 2021. https://investir.lesechos.fr/marches/bitcoin-crypto-actifs/l-expert-l-ingeniosite-et-l-inventivite-du-lightning-network-sont-stupefiantes-1977196.php
38 "The State of Lightning", Arcane Research, October 5, 2021, https://arcane.no/research/reports/the-state-of-lightning
39 Association pour le développement des actifs numériques - ADAN: https://adan.eu/en/
40 Ethereum.org is a public, open source resource for the Ethereum community, to which anyone can contribute. The Ethereum Foundation funds a small team dedicated to the development and maintenance of the site https://ethereum.org/fr/about/

Started in 2014 by Rune Christensen, and materialized in 2018 as a foundation with a white paper published in 2019[41], Maker DAO is a Decentralized Autonomous Organization (DAO) on Ethereum implementing two tokens: the DAI and the MKR. The DAI token is a stablecoin*, meaning it aims to maintain its value as close as possible to one US dollar (USD) through an automated system of smart contracts* programmed on the Ethereum public blockchain. **The service thus allows DAI lenders and borrowers to operate, via a set of smart contracts, the lending, repayment, and liquidation processes**.

As for the Decentralized Autonomous Organization, it gathers the owners of its governance token, the MKR, also programmed on the Ethereum public blockchain, and allows everyone to vote about the evolution of the computer code of smart contracts*. Maker DAO defines itself as "*a stable, decentralized currency that does not discriminate. Any individual or company can benefit from the advantages of digital currency*". By 2021, more than 400 applications and services have integrated DAI as an electronic currency. In October 2020, when one billion DAIs have already been created, the Maker Foundation explains that the most used service is investment to fight inflation, followed by DeFi products and services, then games, digital art, and e-commerce. As of May 2022, that's now 9.6 billion DAIs generated, with a total value of $12.6 billion. "*Many early adopters of crypto-currencies were prompted to explore this technology because of the economic turndown their countries were experiencing*," explains the Maker DAO Foundation.

If it is impossible for these populations to access fiat currencies euros, dollars, yuan via the traditional financial system, the DAI can be easily bought on a decentralized exchange platform (DEX), via a smartphone. The DAI is said to have become particularly well established in Latin America, where countries are subject to high volatility, and by 2020 it will have overtaken Bitcoin in terms of exchange volumes, particularly in Argentina, Brazil, Colombia, and Venezuela[42].

In July 2021, the Maker Foundation said it would cease operations by the end of the year and switch to full decentralization, meaning that governance will be in the sole hands of the members of the Decentralized Autonomous Organization[43], represented by those who own MKR tokens. Maker DAO, open to all, is even attracting banks, such as Société Générale, which has tested a $20 million loan in October 2021[44].

41 DAO Maker - Whitepaper, 2019 https://drive.google.com/file/d/1tPRMktnros6ifJLfvQkrT6mAmEJvUufT/view
42 "The Top Five Ways the Dai Stablecoin Is Used Around the World" MakerDAO, MakerDAO website, Oct 23 2020 https://blog.makerdao.com/the-top-five-ways-the-dai-stablecoin-is-used-around-the-world/
43 "MakerDAO Moves to Full Decentralization; Maker Foundation to Close in 'Months' The move by the protocol's home office has been long expected", Brady Dale, July 20, 2021, https://www.coindesk.com/tech/2021/07/20/makerdao-moves-to-full-decentralization-maker-foundation-to-close-in-months/
44 "Société Générale Applies for $20M MakerDAO Loan Using Bond Token Collateral One of the largest banks in France is working with one of the largest protocols in DeFi on a historic step toward institutional

This Open Finance has been developing since 2018, in parallel with the current financial system, from which it is fundamentally different according to three characteristics: "*it is natively digital; it operates on decentralized infrastructures; it is open to all, both in terms of use, consultation and participation in its construction*" thus explains Clement Jeanneau. According to data aggregator DefiLlama[45], the total value locked in DeFi would reach $245 billion in December 2021, of which $163 billion would be on the **Ethereum** blockchain alone, followed, in order, by the public blockchains **Binance Smart Chain**, **Terra**, **Avalanche**, **Solana**, **Tron**, **Fantom**, **Polygon**, **Arbitrum and DefiChain**. As of June 2022, the total value locked into Defi has fallen to $74 billion.

DeFi allows anyone with financial means, including those without access to traditional loans, to , borrow, lend and invest, insure and trade crypto-assets anywhere in the world without going through an intermediary, with transactions secured via the use of a blockchain and smart contracts. Among the leading applications of DeFi, DEX and lending and borrowing protocols are the most successful. Decentralized Exchange, known as DEX, allows crypto-currencies to be traded without any intermediaries, or Centralized Exchange Platform (CEX).

Uniswap, launched in November 2018, is the first DEX, allowing its users, from a simple wallet, to exchange ERC20 tokens based on the **Ethereum network**, as well as **PancakeSwap**, a decentralized exchange of BEP20 tokens, based on the **Binance Smart Chain**, or **Curve Finance**, founded in 2020, another DEX built on the Ethereum network, allowing the exchange of stablecoins at reduced fees using, among other things, an Automated Market Maker (AMM[46]) protocol.

Lending and borrowing protocols such as **Nexo**, **Aave**, or **Compound**, (all three created in 2017), are open source protocols that allow their users to invest and earn interest on their crypto-currencies, depositing them in one of the liquidity pools supported by the platform or to borrow crypto-currencies by depositing collateral often as high or even higher than the amount borrowed. A wide range of crypto-assets can be deposited, including the previously mentioned Maker DAO.

Another DeFi offering is specifically aimed at small and medium-sized enterprises, such as **FintruX**, founded in Singapore in 2017, or **TrafiGuard** in 2020, built on **Bloom**[47] and **0x**[48] platform, an open source protocol that enables peer-to-peer asset exchange on the Ethereum blockchain.

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adoption", Andrew Thurman, October 1, 2021, https://www.coindesk.com/business/2021/09/30/societe-generale-applies-for-20m-makerdao-loan-using-bond-token-collateral/

45 Defi Llama: defillama.com

46 An automated market maker (AMM) is a type of decentralized exchange protocol (DEX) that relies on a pricing algorithm to value assets. An AMM functions similarly to an order book exchange by establishing trading pairs - for example, BTC/DAI except that, because the trading is decentralized, the originator interacts with a smart contract whose liquidity comes from other users called liquidity providers (LPs).

47 "The Truth Platform", Bloom, retrieved May 10, 2022, https://bloom.co/

48 "Introduction to Ox", Ox, retrieved May 10, 2022, https://0x.org/docs/core-concepts

This offering is in line with Sustainable Development Goal 9, specifically target 9.3, "*increase, particularly in developing countries, access to financial services, including affordable loans, for enterprises, especially small industrial enterprises, and their integration into value chains and markets*[49]".

Bloom bills itself as "*an end-to-end identity attestation, risk assessment and credit scoring protocol built on the Ethereum blockchain. Bloom enables traditional and digital currency lenders to serve billions of people who are currently unable to obtain a bank account or credit score*[50]". **TrafiGuard**, by leveraging **Bloom**, hopes to launch a "*trade finance solution for micro and small businesses*[51]" by bringing together international buyers and sellers in a new way.

TrafiGuard allows the buyer/importer to deposit funds into a smart contract created on Bloom. These funds, deposited in USDC stablecoin (indexed on a dollar) are blocked in a smart contract that generates interest and allows the seller/exporter to contract, on the spot, a loan in his local currency.

To prove creditworthiness, the seller/exporter identifies himself on Bloom, provides local tax documents, provides the Bill of Lading, the legal document issued by a carrier to a shipper detailing the type, quantity, and destination of the goods being transported, and finally, verifiable information related to international transport. Depending on the risk score calculated by Bloom, the seller/exporter will be able to take out a loan of between 10% and 50% of the security deposited by the buyer/importer.

All documentation proofs are provided to the smart contract via **Chainlink's** decentralized oracle networks. The nested blockchain protocols are thus **Bloom**'s, which enables the deployment of smart contracts, Chainlink's oracle, to certify external data, the **Compound** lending and borrowing service (see above), and the stable crypto-currency USDC to ensure cross-border financial exchanges.

While the process may seem complicated at first glance, it is an opportunity for a seller/exporter to access an innovative financing solution that they will never have access to with the traditional financial system.

49 Sustainable Development Goal 9: "Access to financial services for all enterprises". https://www.agenda-2030.fr/17-objectifs-de-developpement-durable/article/odd9-mettre-en-place-une-infrastructure-resiliente-promouvoir-une
50 "What is Bloom ?", Bloom, retrieved May 10, 2022, https://faq.bloom.co/article/5-what-is-bloom
51 "How TrafiGuard uses Bloom to Provide SME Financing on the Blockchain", David Raphael, March 17, 2021, https://bloom.co/blog/how-trafiguard-uses-bloom-to-provide-sme-financing-on-the-blockchain/

Complementary local currencies

A complementary local currency is a currency created as a complement to a national currency, to be exchanged in a given geographical area to "*improve local exchanges and boost the real economy*[52]".

In developed countries, complementary local currencies are a monetary tool aimed at stimulating a socially and environmentally responsible economy, by relocating supplies through short circuits and by incentivising sustainable practices of businesses and individuals[53].

There are few "local crypto assets" even though similar initiatives, with a very different regulatory context, have taken place in Kenya with **Grassroot Economics** or in Switzerland with **Leman**[54]. In developing countries, when national currency becomes scarce because a country's economy contracts, the most disadvantaged people no longer have the means to exchange goods and services with each other.

Since 2010, **Grassroots Economics** has implemented community inclusion currency (CIC) programs in more than 45 communities in Kenya, helped roll out two community currencies in South Africa and Congo, and supported several projects outside of Africa. It has also trained people to design community inclusion currencies in Colombia, Nigeria, and France.

As a nonprofit foundation, Grassroots Economics seeks to "*empower marginalized communities to take charge of their own livelihoods and economic futures, including through economic empowerment programs*." In 2018, Grassroots Economics moved from a "traditional"[55] complementary currency model, which took the form of a paper-based voucher circulating alongside the national currency, the Kenyan shilling, to a digital model and managed via a blockchain protocol with a token.

This community inclusion currency project is open source and extremely well documented, both technically and operationally[56], including online courses (MOOCs) to learn how to develop a paper community currency before training to deploy a complementary currency based on their blockchain. Furthermore, Grassroots Economics is blockchain agnostic and does not hesitate to switch blockchains to optimize the technical architecture and usability of the service as best as possible.

In 2018, Grassroots Economics used **Bancor**, a smart-contract protocol based on Ethereum and **Atomic Swap** to issue

52 Monnaie locale complémentaire : https://www.novethic.fr/lexique/detail/mlc.html
53 "Le numérique au secours des monnaies locales et complémentaires", Bénédicte Martin, Netcom, journals.openedition.org, 18 décembre 2018, retrieved December 15, 2021.
54 "Le Léman, concrètement ?", Monnaie Leman, https://monnaie-leman.org/le-leman-concretement
55 Before Grassroots Economics went fully digital, they built community currencies using paper vouchers from 2010 to 2018 in Kenya. Their MOOC gives some explanation of how and why they did this: https://www.grassrootseconomics.org/pages/mooc.html
56 "Karibu to Grassroots Economics Docs ", Grassroots Economics, retrieved May 10 ,2022, https://docs.grassecon.org/

inclusive community currencies and make them convertible. In 2021, Grassroots leveraged the MakerDAO blockchain (see above) to implement new peer-to-peer complementary currency programs.

In 2021, Grassroots relied on xDai chain, MakerDAO's public blockchain (see above) to issue CICs, while Uniswap took over from Bancor. These two changes allowed Grassroots to regain control of its CIC conversion system while lowering transaction fees.

Since 2022, Grassroots has been developing its own blockchain, the Kitabu chain, created from a copy of the public blockchain licensed by Bloxberg.

The Kitabu chain has the advantages of being able to operate without an internet connection, and most importantly, not charging transaction fees to CIC recipients.

A study published in January 2022[57] was conducted by Rebecca Mqamelo of Minerva University in the United States and focused on analyzing the use of Grassroots Economics' community inclusion currency run on MakerDAO's xDAI blockchain (see "Peer-to-Peer Electronic Cash System and Programmable Money" Chapter).

The study presents the results of what may be the world's first randomized control trial of a community currency.

Recipients in Nairobi, Kenya, received the equivalent of $30 in crypto-currency tokens, allowing for an impact analysis of the money transfer program. The results, which have been made public, show that the community inclusion currency circulation is fulfilling its role as a financial vehicle and also highlighted "*differences in treatment effects for men and women, suggesting that gender imbalances persist*." This is one of the first quantitative and qualitative studies in the field of "Crypto for Good," showing that "*community inclusion currencies are a powerful tool for communities to change the structure of their local economies from within*[58] ."

57 "Community Currencies as Crisis Response: Results From a Randomized Control Trial in Kenya" www.frontiersin.org Rebecca Mqamelo* Minerva University, San Francisco, CA, United States, January 3, 2022. https://www.frontiersin.org/articles/10.3389/fbloc.2021.739751/full#h1
58 *Ibid.*

Insurances

The insurance market is concentrated in the hands of a few large international groups, including AIA Group Limited (Hong Kong), China Life Insurance (China), and Prudential plc (UK). These insurance giants started to take an interest in blockchains in 2018, mainly to make payment processes smoother or to try to spot fraud. Blockchain projects in the insurance industry emerged two years earlier, including the creation of **Etherisc** in 2016 in Munich, Germany, by Christoph Mussenbrock, Stephan Karpischek, and Renat Khasanshyn or **Arbol**, created in New York in 2018.

Etherisc is developing a "*protocol for decentralized insurance*[59]", to, among other things, make "*buying and selling insurance more efficient than with traditional insurance, but also allow for a reduction in operational costs while providing better transparency of operations*[60]".

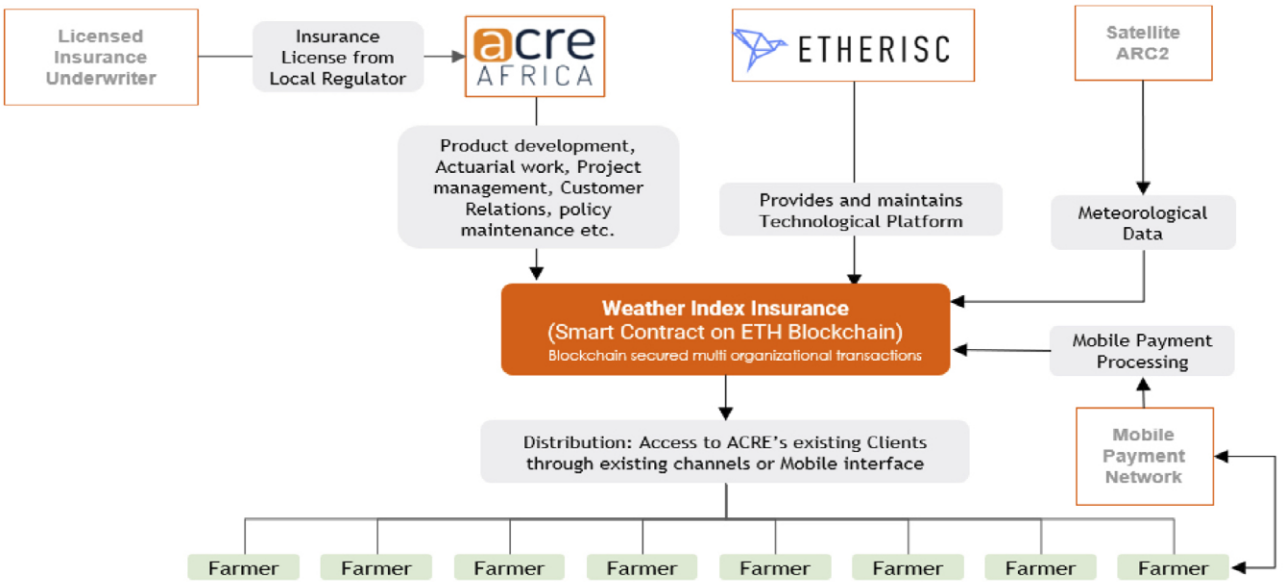
Based on the public Ethereum blockchain, Etherisc is developing a protocol, smart contracts, and a blockchain platform called the Generic Insurance Framework. By providing this open source, open-access infrastructure for decentralized insurance, anyone who wants to create their own insurance products can use the platform.

Around 30 applications have already been tested, from commercial insurance to dedicated non-profit solutions such as mutuals, peer-to-peer insurance, cooperative models, or even new insurance structures, such as the one launched in Kenya in October 2020. In this country, the traditional insurance offer would fail due to "*insufficient coverage, delays in payments, high premium costs and lack of transparency and trust*"[61].

Etherisc, along with Agriculture and Climate Risk Enterprise Ltd (ACRE), a licensed insurance intermediary that provides risk management solutions to mitigate agricultural and climate risks in Kenya, has set up a decentralized insurance for local farmers that is fully automated and indexed to weather conditions, with support from Chainlink and the Ethereum Foundation. Launched in November 2020, a year later it had "*12,567 insured farmers with at least 511 small farmers able to receive a mid-season payment during the long 2021 rainy season*[62]".

The process is as follows: a farmer pays for seed, the price of which includes a parametric insurance premium, i.e., insurance correlated to weather conditions; the farmer planting the seed uses an SMS-generated identifier with a simple feature phone* to provide both personal and agricultural information.

59 "Make Insurance Fair and Accessible", Ethersic, Ethersic website, retrieved May 10, 2022, etherisc.com/
60 *Ibid.*
61 "Reunion with our Partners In Nairobi: A recap of Etherisc's week in Kenya", Etherisc, https://blog.etherisc.com/reunion-with-our-partners-in-nairobi-a-recap-of-etheriscs-week-in-kenya-a0560ffea77f
62 "Reimagining agriculture insurance using blockchain technology", Jean Eyase, Acreafrica.com, November, 11, 2021, https://acreafrica.com/reimagining-agriculture-insurance-using-blockchain-technology/



System and relevant actors of the Etherisc Weather Index Insurance in Kenya
Source : Blockchain for Climate Action and the Governance Challenge Report from INATBA and CLI, https://climateledger.org/resources/Blockchain-for-Climate-Action-and-the-Governance-Challenge.pdf

Once the decentralized insurance contract is launched, the program interacts autonomously according to the data corresponding to the farmer's insurance. ACRE offers four types of insurance[63] :

(1) Weather-indexed coverage, based on rainfall data collected by satellite. Coverage is triggered when rainfall falls below certain thresholds determined by the crop's needs;
(2) Soil moisture index coverage, based on soil moisture data also collected by satellite. The coverage is triggered when soil moisture is below certain thresholds determined according to the needs of the crop;
(3) a vegetation index, based on vegetation cover, adapted for arid and semi-arid areas. The cover is triggered when the amount of vegetation is less than the amount sufficient to support animal life. And finally, (4) a multi-hazard crop cover that covers the farmer in the event of drought, excessive rainfall, flooding, hail, windstorms, frost, or fire, the list goes on.

Moreover, rather than relying on a trusted, centralized third party to obtain weather data, the smart contract is connected to "Decentralized Oracle Networks", i.e. offered by a panel of intermediaries who provide external and verified information via another blockchain or any other service. The oracle used by Etherisc for this program is Chainlink, a Decentralized Oracle Network created in 2017 in New York, USA, by Sergey Nazarov and Steve Ellis.

63 "Who we are", ACRE Africa, ACRE Africa website, retrieved May 10, 2022, https://acreafrica.com/

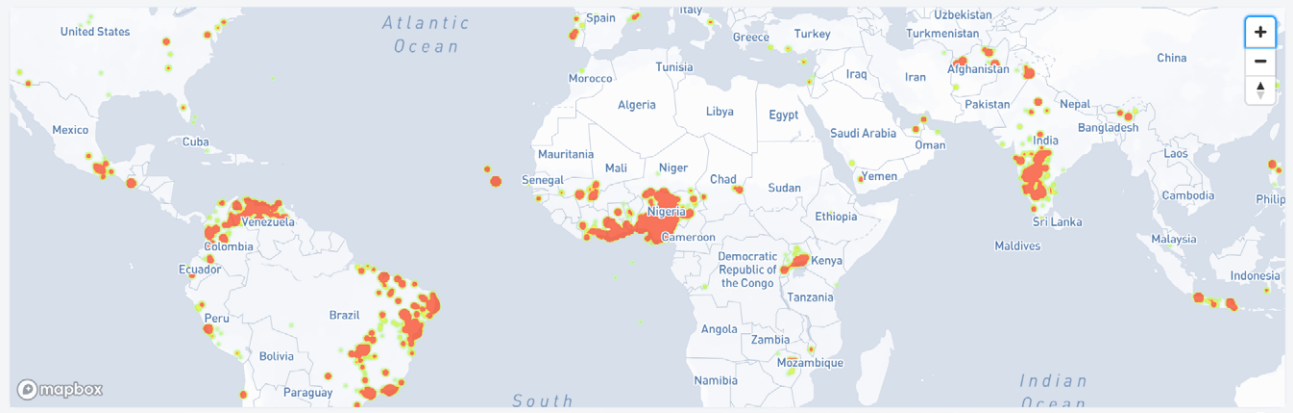


Tableau de bord global Impact Market
Source : https://impactmarket.com/fr-FR/global-dashboard

As of December 2021[64], more than 1,000 blockchain projects rely on the decentralized oracle network created by Chainlink within which $77 billion of crypto-assets are secured on the network, in smart contracts*.

The **Chainlink** network is maintained by some 700 nodes that implement hybrid smart contracts, i.e. based on components that run both on-chain*, on a blockchain, any blockchain, and components that run off-chain* on their decentralized oracle network, and which guarantee data integrity, veracity, and confidentiality.

Chainlink is thus integrated with Etherisc's smart contracts* to provide real-time weather data. When a weather event covered by the smart contract* occurs, the contract automatically triggers the compensation payment. This solution would, according to the INATBA[65], "*reduce premiums by up to 30% and reduce the claims cycle from three months to one week (...) and payments are made via M-PESA, directly on the farmer's cell phone*".[66]

All payments are recorded on Etherisc's blockchain to provide transparency of transactions. Etherisc said 6,000[67] farmers are expected to be compensated before the end of the 2021 season via the M-Pesa mobile payment system for their lost or affected crops. ACRE and Etherisc aim to insure 250,000[68] farmers in West Africa in the coming years.

64 "Chainking data feed", Chainlink, Chainlink website, retrieved May 10, 2022, data.chain.link/
65 International Association for Trusted Blockchain Applications: https://inatba.org
66 "Climate Action and Governance with Climate Ledger Initiative", INATBA, June 1, 2021, https://inatba.org/reports/climate-action-governance-challenge/
67 "Etherisc onboards 17K Kenyan farmers covered by blockchain-based crop insurance", Turner Wright, cointelegraph.com Jul 21, 2021, https://cointelegraph.com/news/etherisc-onboards-17k-kenyan-farmers-covered-by-blockchain-based-crop-insurance
68 *Ibid*.

Universal Income

According to the definition of the French Movement for a Basic Income (Mouvement Français pour un Revenu de Base), "*the basic income, also called existence income, unconditional income or universal allowance, is an income paid by a political community to all its members, on an individual basis, without conditions of resources or work obligation*"[69].

For what amount? To whom? For how long? Who finances it? What impact on society and work? The countless questions linked to the implementation of a universal income have been raised since the 17th century, notably by Locke and the "Lockean clause", which justified a universal allowance as the counterpart to private property of the land for the benefit of those who did not benefit from it.

These questions remain contemporary and are being raised by philosophers and thinkers, but also by institutions, unions, international organizations, and associations, regardless of their political affiliation.

Several blockchain initiatives seek to implement forms of universal income or basic income, including Circles (2015) carried by the Trustlines Foundation, GoodDollar (2017), Baza Foundation (2018), Idena (2019) or ImpactMarket (2020), in different forms. For example, Baza Foundation presents itself as "a *digital platform built with the goal of reimagining a nonprofit organization by adapting the principles of basic income, smart contracts and secure ledger technology*[70]". Circles, powered by Trustlines Network explains that it is "*an alternative currency that allows organized groups of people to provide each other with a basic income, rather than depending on the state*"[71].

69 "Revenu de Base", Novethic, retrieved May 10, 2022, https://www.novethic.fr/lexique/detail/revenu-de-base.html
70 "Baza Coin", Baza Foundation, Baza Foundation website, retrieved May 10 2022, https://baza.foundation/
71 "A basic income system for communities", Join Circles, Join Circles website, retrieved May 10, 2022, https://joincircles.net/

Impact Market, on the other hand, defines itself as a decentralized anti-poverty protocol that enables the creation and distribution of an unconditional basic income between communities and their beneficiaries, based on their needs. Impact Market presents itself as a decentralized protocol for poverty alleviation. It is a Decentralized Autonomous Organization* (DAO) using a token called $PACT. The protocol uses Celo's cUSD as its primary digital currency, while operating autonomously through smart contracts*. Since Impact Market's inception, 236 communities in 44 countries around the world, including Brazil, Venezuela, Kenya, Ghana, India, Nigeria, and Cape Verde, have been receiving a form of monthly income funded by donations and managed locally by "*community leaders and social, governmental, or local organizations, who set the initial parameters and add/remove beneficiaries*".[72]

Each community receives a "*daily stipend per beneficiary*," ranging from the equivalent of 0.5 cents to $1.5. Brazil, Nigeria, and Venezuela have the largest number of beneficiaries. As of May 2022, 5,233 donors have contributed $2,632,313.64 cUDS (Celo) to 43,810 beneficiaries who receive an average of $0.55 per day for an average of 40 months.

Impact Market has three communities interacting within a Decentralized Autonomous Organization*:

(1) "Community managers", in charge of submitting a community for approval and then managing its beneficiaries. These are usually local social institutions that have direct access to the final beneficiaries and address as much as possible those who need it most quickly. A community manager applies online, providing a certain amount of information as well as the details of a basic income contract for the beneficiaries. Once accepted as a community manager, the individual(s) will be able to add beneficiaries who can then claim assistance matching the funds available. Two mobile apps, linked together, are required, the Valora app, a DApp-enabled mobile crypto-currency wallet built on the Celo blockchain, and the impactMarket app, allowing for community management.

(2) Beneficiaries, the people who will have access to a basic income. They will need to be equipped with a smartphone and download both the Valora and ImpactMarket apps.

(3) Donors, those who make a donation to support the project. When donors make a donation to DAO in cUSD, they become eligible to receive $PACT tokens as a reward. Donors can also choose to specifically help a community, visible on the Valora app[73].

72 "Impact Market Dashboard", Impact Market, retrieved May 10, 2022, https://www.impactmarket.com/fr-FR/global-dashboard
73 "If you can text, you can crypto", Valora, Valora website, retrieved May 10, 2022, https://valoraapp.com/fr

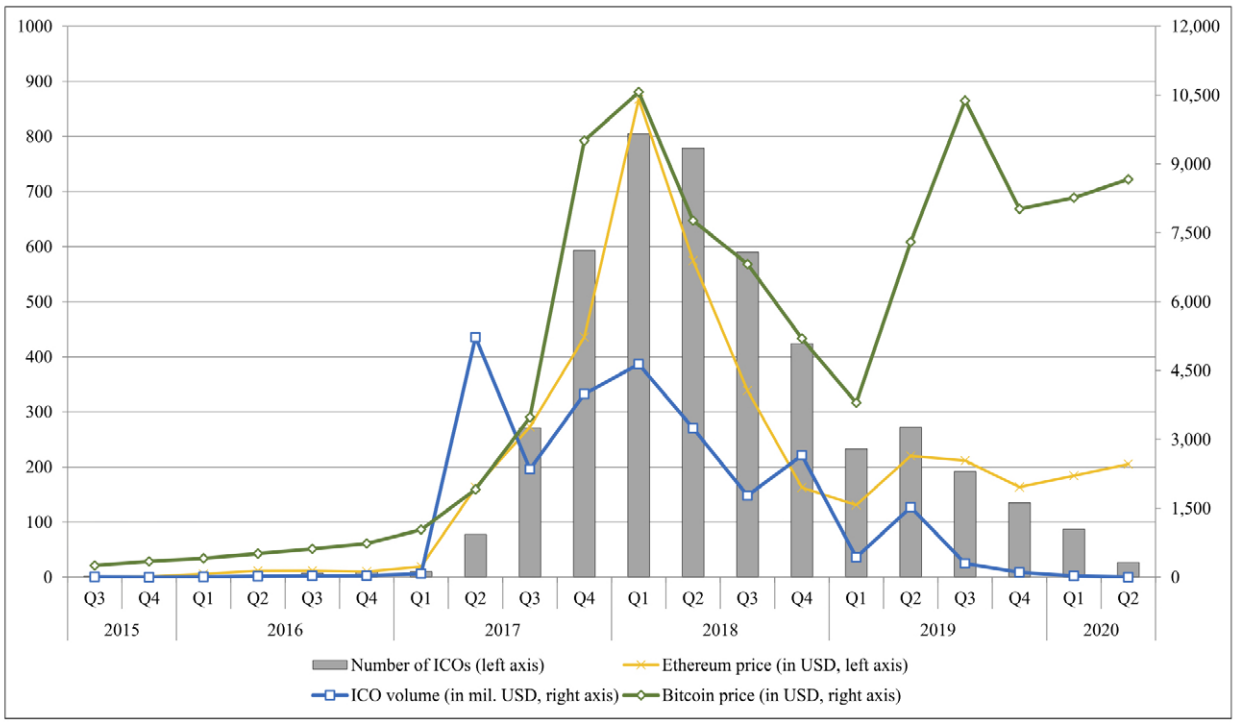


Fig. 1. Evolution of the number of ICOs, ICO volume, and Bitcoin price.
Source : Bellavitis, C., Fisch, C., & Wiklund, J. (2021). A comprehensive review of the global development of initial coin offerings (ICOs) and their regulation. Journal of Business Venturing Insights 15 (2021). doi:10.1016/j.jbvi.2020.e00213

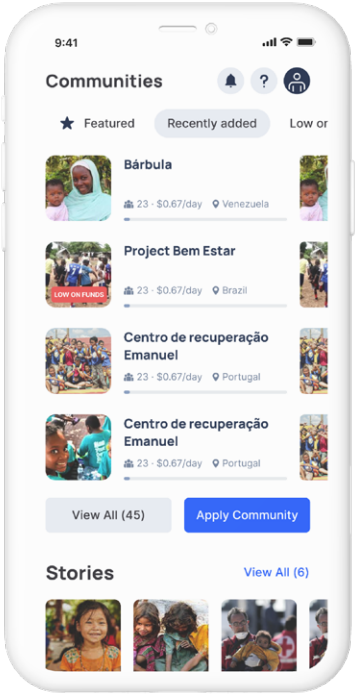
In addition to cUSD, donors can donate in fiat currency, Bitcoin, Ether, or *via* Paypal using eSolidar, but they will not receive a $PACT token as a reward.

A fourth community can also participate in the ecosystem, local merchants, who can accept cUSDs, so that beneficiaries can buy food, electricity, water, and other products or services of daily life. Impact Market uses the Celo Dollar, (cUSD), a dollar stablecoin deployed by Celo whose transaction fees are typically around 0.001 USD per transaction.

The ecosystem is decentralized because donors choose where to direct their funds, and smart contracts are responsible for distributing them according to the terms of the universal income contract of the targeted community.

At the local level, community managers do not handle funds but open and close accounts for recipients who receive aid directly into their cryptocurrency wallets. ImpactMarket's open source protocol is governed by $PACT token holders who vote on proposals.

The DAO is made up of three smart contracts*, through which everything that happens on the protocol goes through the voting of “proposals” that concern all decisions made by the DAO, such as, for example, updating a contract for the allocation of funds from the treasury, creating or closing communities, etc. It is also possible for a humanitarian or international organization to use ImpactMarket by funding the fund with the amount of aid provided in order to manage the program's beneficiaries on the ground.



Impact Market community
Source : Impact Market, retrieved May 10 2022, https://docs.impactmarket.com/communities/how-to-apply-a-community

Good Dollar or "Staking for Good"[74]

Good Dollar is an NGO created by Yoni Assia, CEO of eToro, a multi-currency trading company founded in 2007 in Israel. After publishing an essay in November 2008 entitled "Good Dollar - The Visible Hand" introducing the concept, it was in 2018 that the project was launched. Good Dollar is an online tool to distribute a universal basic income in a crypto-currency called G$, which relies on the DeFi protocols of the Ethereum blockchain and the Fuse.io sidechain.

The computer code, open source, brings together three communities: (1) The funders: Rather than contributing directly to the Good Dollar funds, the funders deposit DAI (MAkerDAO) or ether (Ethereum) in staking protocols* or third-party mechanisms via the GoodDollar Trust and, rather than receiving the interest on this asset, the latter are paid into the Good Dollar treasury (2) Beneficiaries of the UBI: The universal nature of Good Dollar only requires that in order to receive Good Dollar tokens, one must register, download a wallet and claim the Good Dollar generated by the staking operations of the funders on a daily basis. Each day, Good Dollars are distributed among all beneficiaries who have claimed them. As of May 2022, 2.4 million Good Dollars were distributed daily, the equivalent of US$454.

(3) Finally, merchants are those merchants who accept payment in Good Dollar, which can be converted into other crypto-currencies, including ethers and DAI. According to the data presented by Good Dollar[75], $542 million B has been paid to 427,549 people since the project's inception, which is equivalent to $90,651. As of May 2022, $1B = $0.00018. As of April 2021, the countries with the highest demand for G$ are Nigeria, Vietnam, Brazil, India and Indonesia.

Crowdfunding

Crowdfunding, not to be confused with an initial coin offering (ICO*), is an operation that consists of raising funds via the issuance of digital assets that can be exchanged for crypto assets, during the startup phase of the project.

The interesting aspect of this fundraising process is that it is accessible to anyone who owns crypto-assets, without the intervention of a financial institution or a regulator.

Blockchain projects are renewing the centralized nature of traditional crowdfunding platforms, including **eSolidar**, **ImpactMarket**, **Suretly**, **Topl**, **IcrowdU**, or even **Raise** or **WeiFund**.

For example, the startup **Raise** created in Nairobi, Kenya in 2017 is developing, according to its founder Marvin Coleby, a

74 "The GoodDollar Basic Income Economy", Gooddollar.org, retrieved May 17, 2022, https://whitepaper.gooddollar.org/the-gooddollar-basic-income-economy#staking-for-good
75 Good dollar Dashboard, retrieved May 17, 2022, https://dashboard.gooddollar.org/

platform that "*prepares startups to raise funds through an automated capitalization table, electronic share certificates, and a company and technology valuation*."

Among the various services offered by the platform is the ability for shareholders to easily and securely view data related to their investments. Fund recipients can also issue digital shares and convertible certificates to reduce the administrative procedures and operational costs of traditional fundraising[76]. Raise offers a platform that automates the financial and regulatory aspects of fundraising to help startups in the African ecosystem. Or WeiFund, founded in Toronto in 2015, is a non-profit, decentralized, and open source crowdfunding platform built on Ethereum. WeiFund turns contributions into contractually-backed digital assets, such as shares or tokens, which can be used, traded, or sold in the Ethereum ecosystem.

Co-funded by the European Union through the Smart Growth program and Poland's National Research and Development Center, Tecra has been developing a decentralized crowdfunding platform, Tecra Space, since 2018, backed by a crypto-currency, TecraCoin (TCR), which is currently exchangeable on the centralized exchange Hotbit and the decentralized exchange Uniswap DEX, prior to the development of their own decentralized exchange, Tecra DEX[77]. According to the company, Tecra "*offers scientists and innovators an easy way to raise funds through crowdfunding, benefit from patent security and reduced fees, as well as quick paybacks after the project's profits are realized* ".[78]

Each project launched *via* the crowdfunding platform will come with its own token, which can be purchased with Ether, the stablecoin Tether, or TecraCoin, but also by credit card, PayPal, or bank transfer. The minimum investment is one TCR, which is between 50 cents (price on January 1, 2021) and two dollars (price on July 7, 2021). From a technical point of view, TecraCoin is an ERC-20 token registered on a public permission blockchain based on Ethereum[79], similar to the Clique or Aura blockchain. TecraCoin is a deflationary crypto-currency whose number of pre-mined tokens will be gradually reduced (burned) by validation nodes. Tecra won the Startup Grand Slam at the 2019 World Blockchain Summit in Taipei and was also a Singularity University finalist for the Top 10 Eastern European Startups award at the Google Campus in Warsaw.

In December 2021, twelve years after its inception Kickstarter announced that it would switch its centralized crowdfunding

76 "How Raise works to help prepare your startup for investment", Marvin Coleby (CEO), Intercom website, retrieved 10 May, 2022, https://intercom.help/raise/en/articles/3665904-what-is-raise
77 "Crypto crowdfunding platform launches DEX for project-specific tokens", Connor Sephton, Cointelegraph website, May 24, 2021, https://cointelegraph.com/news/crypto-crowdfunding-platform-launches-dex-for-project-specific-tokens
78 Tecra: https://tecra.space/
79 "Tecra Space Warsaw", Krzysztof Bochenek, PO Poland, January 20, 2021, https://www.24-7pressrelease.com/press-release/478789/europe-is-gearing-up-for-the-blockchain-revolution-altcoins-on-the-rise

platform to a new model, this time decentralized, and which will be based on the Celo blockchain (see above). According to its founder Perry Chen, "*in the coming years, we believe that large parts of the internet will be entirely rebuilt by open and decentralized networks of contributors, who participate in the design, operation, governance and even ownership of the technology itself.*"

Financial Inclusion

If there is such a thing as inclusive finance, it is because finance, in its traditional form, excludes. The traditional one is based on banks and financial institutions. Inclusive finance was born between the 1970s and 1980s with the modern microcredit developed by the Bangladeshi economist Muhammad Yunus, who was awarded the Nobel Peace Prize in 2006. It has since developed by trying to adapt the regulations of the traditional financial system to microfinance, crowdfunding, cell phone banking, etc. for the most disadvantaged people, excluded from the banking system.

Hiveonline launched in 2016 in Denmark, **Waba**, created in Argentina in 2017, or **Ethic Hub**, created in 2019 in Spain are some of these initiatives. For example, Ethic Hub, created in 2019 in Spain, is a social enterprise that connects investors with small farmers. The latter can complete their crops, especially coffee, and sell them in markets without intermediaries so that 50% of the profits go directly to them[80].

EthicHub is particularly aimed at unbanked farmers in Mexico. The team has developed a peer-to-peer financing platform (crowdlending) where many small investors, 20 euros minimum, finance the agricultural activities of small farming communities while receiving interest on the loans.

In 2020, Ethic Hub decided[81] to migrate its operations from the Ethereum blockchain to xDai Chain, an Ethereum-based sidechain* or Layer 2 that uses a proof-of-stake* based consensus mechanism. Launched in late 2018, xDai Chain uses the stablecoin, xDai, as its native cryptocurrency.

EthicHub thus solves several problems, including, in particular, the speed of execution and, above all, the cost of transactions. Since its launch in 2019, EthicHub has received more than 7,000 micro-investments, distributed to 240 farmers in 17 communities, indirectly impacting nearly a thousand families[82].

Hiveonline describes itself as a company providing access to credit and markets for financially excluded smallholder farmers and their local ecosystems. One of Hiveonline's platforms relies on "*a blockchain to securely distribute vouchers and a stablecoin to provide digital money in local currency with secure and immutable records*." The company likes to say it is doing "sustainable digital finance without phones" (see sample project at the end of the chapter).

80 "Specialty Coffee" EthicHub, retrieved May 10, 2022, https://shop.ethichub.com/en
81 "Why did we start using xDai in EthicHub ?", Equipo EthicHub, EthicHub website, retrieved May 10, 2022, https://help.ethichub.com/hc/en-us/articles/360013429458-Why-did-we-start-using-xDai-in-EthicHub-
82 "Inversión de Impacto Protegida", EthicHub, retrieved May 10, 2022, https://www.ethichub.com/

Impact investment

Social impact investment is defined as "*an investment that explicitly combines social return and financial return on investment*"[83]. It is about offering investors, whether individuals or companies, to finance projects with positive social or environmental impacts. Because the use of a blockchain makes it possible to dispense with intermediaries between an investor and his beneficiary, many initiatives based on a blockchain have emerged, including the **Sun Exchange** platform.

Founded in South Africa in November 2015 by Abe Cambridge, The **Sun Exchange** platform (which we also discuss in the "Energy" chapter) aims to democratize renewable energy financing through crowdfunding. It is a micro-lease marketplace that connects investors, individuals, and companies, with beneficiaries of solar installations in rural South Africa, with the promise of a 10% return on a 20-year contract. The platform uses the Bitcoin blockchain for cross-border payments so that there is no middleman between the installation beneficiaries who pay for their electricity and the investors who participated in the purchase of the solar panels.

Following an initial crowdfunding campaign between January and November 2015, the company built its first solar power plant at a school in the Cape Town area. Three years later, the platform had 6,000 registered investors and built seven solar power plants. By 2022, more than 40 solar power plants with a total electrical capacity of 5.2 GWh of clean energy have been created, thanks to the investment of individuals and companies in 180 countries around the world.

The beneficiaries of the photovoltaic installations are mainly schools, old people's homes, small and medium-sized enterprises, nature parks, and non-profit organizations, which now pay 20-30% less for their electricity bills. The savings are used to provide quality education for children, positive living environments for elderly residents, and care for vulnerable wildlife, among other things.

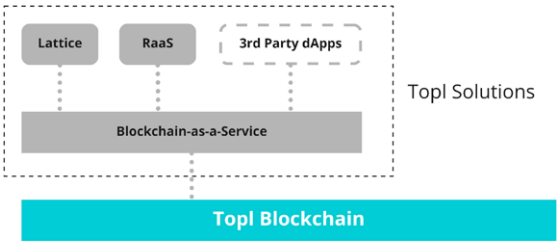
83 French Committee on Social Impact Investment, https://www.vie-publique.fr/1388-secretariat-detat-au-commerce-lartisanat-la-consommation-et-leconomie-sociale-et-solidaire

Impact verification

Topl, **Ixo Foundation**, or **Proof of Impact** are some of these initiatives with the aim of "tokenizing" the impact of organizations' activity.

Topl, created in Houston in the United States in 2017, presents itself as an "*ESG technology company that builds a blockchain to help companies prove ethical and sustainable practices*".

It is an entire ecosystem that the company wants to develop, including two tokens, a first of governance as well as a stable crypto-currency, and all the bricks will be developed by the end of 2022.



The Topl blockchain will be a public, open source blockchain based on proof-of-stake*.

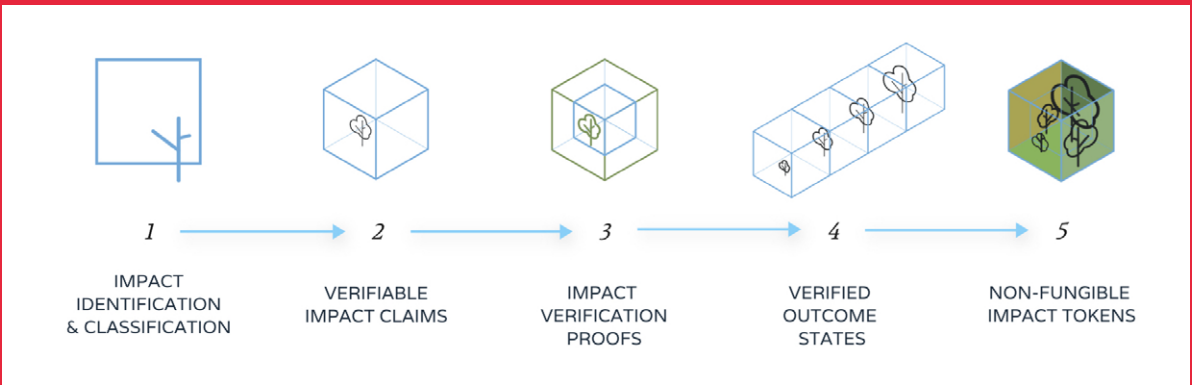
IXO Foundation was also established in 2017, in Zug, Switzerland. The IXO Foundation is developing the protocol of the same name on the Cosmos public blockchain. The goal of the IXO protocol is to record "verifiable facts" in a public blockchain, including data related to the environment, economy, and climate impacts. The idea is to add sustainability mechanisms, Sustainable DeFi, to decentralized finance, determined by extrinsic real-world state changes: a renewable energy certificate, a carbon credit certificate, and other "verifiable facts," in particular thanks to the fact that *"real-world state changes can now be monitored, verified and reliably attributed to identified agents, entities, events and investments"*[84] explains the IXO Foundation website.

IXO is built on the Cosmos public blockchain, which aims to become the "internet of blockchains" by providing secure interoperability between services of different public blockchains. Based on the Cosmos ecosystem, IXO can interact with any other blockchain on Cosmos but also use bridges to other ecosystems such as Ethereum, Cardano, or Polkadot. IXO's activity started in 2015, first within the TrustLab based in South Africa, funded by UNICEF innovation funds, as well as another impact fund called Innovation Edge[85] to develop the first project, Amply.
Amply[86], conducted with UNICEF and the South African government, involved digitizing the management of a South African education program by recording the kindergarten attendance of disadvantaged children on the Ethereum blockchain and issuing tokens as proof of impact in exchange for government grants.

84 Ixo Foundation: https://www.ixo.world/protocols
85 Innovation Edge, retrieved May 17, 2022, https://innovationedge.org.za/
86 "Impact Tokens: A blockchain-based solution for impact investing", David Uzsoki, Patrick Guerda, International Institute for Sustainable Development | IISD.org, https://www.iisd.org/system/files/publications/impact-tokens.pdf

IXO Foundation's Impact Tokenization

Source: https://www.ixo.world/protocols



1. Impact Identification

Observations about the state of the world are identified, using decentralised identifiers (DIDs) and classified for semantic context, using linked-data schemas.

2. Impact Claims

Verifiable Impact Claims are issued and cryptographically signed by identified, authenticated agents. Using client applications, such as the ixo mobile Impact Wallet, to capture the claim data at the implementation edge of the real-world processes which are creating and observing change.

3. Impact Verification

Impact claims, with their high-definition data assets as evidence, are evaluated by independent, certified Verification Agents. Verifiers use standardised evaluation rubrics and statistical methods to form opinions on whether each claim can be approved. They issue Verification Proofs which attest to whether claims meet the requirements to be approved.

4. Impact Credentialing

Collections of verifiable claims over time, together with their verification proofs and additional information – such as the verifiable credentials of a project implementer, are combined to issue a Verifiable Credential for an Outcome State. Which includes a graph of the claims, proofs and credentials.

5. Impact Tokenization

Impact Tokens are minted with graphs of data assets as Linked Resources, which can be retrieved by authorised users from specified service endpoints – such as ixo Cellnode confidential data stores, in a permissioned way, using Authorization Capabilities (zCaps). Non-fungible Impact Tokens can be configured into outcomes-based financing mechanisms, such as Alphabonds, traded as digital assets, or used to create new types of stakeholder-centric ownership schemes and participation mechanisms.

Indeed, the South African government had set up a $200 million subsidy program for 800,000 disadvantaged children. In order to access the grants, teachers had to report their attendance or non-attendance in paper notebooks and submit them quarterly to administrators in the Department of Social Development, who then released the grants on a school-by-school basis.

With Amply, each child was assigned a decentralized digital identity so that teachers could record their attendance by generating a verifiable certificate (see "Identity and Ownership" chapter).

The verifiable credentials and associated metadata (location, date, time of collection) were then verified by Ministry of Social Development administrators, generating, through a smart contract, an impact token that the school then used to obtain the government's planned grant. According to the International Institute for Sustainable Development, "*apps like Amply can reduce fraud and costs associated with these programs while giving service providers and funders valuable insight and proof that their money is being well spent. The data is accessible on the blockchain by anyone, and it allows governments, researchers, donors, and NGOs to make more informed decisions about their work to maximize impact*"[87].

This pilot project then evolved into a larger contract in India to repeat the experience through the "Quality Education India DIB," launched in 2018 at the United Nations General Assembly in New York with the Indian government in Delhi.

Protean and even complex to grasp, the IXO platform offers "*an open standard for producing verifiable statements* about changes in the state of the world*"[88]. Each impact token represents a "verified outcome statement," in the form of a non-fungible token* (NFT), which is backed by impact data assets and verification evidence, with built-in enforceable rights.

For the Foundation, impact tokens will be brought to replace all tradable instruments such as "*verified emissions reduction certificates for carbon credits, renewable energy certificates for clean energy, qualification certificates for educational outcomes, biodiversity certificates for nature outcomes, immunization certificates for health outcomes, or any other verified outcome state that people care about, are willing to invest, work for, or spend their money on*"[89].

The data to prove "evidence of a state" in the real world comes from a variety of sources, including Internet of Things (IoT) sensors, surveys from an authenticated user, satellite imagery, or data collected from the connected devices of project participants.

87 "Impact Tokens: A blockchain-based solution for impact investing", David Uzsoki, Patrick Guerda, International Institute for Sustainable Development | IISD.org, https://www.iisd.org/system/files/publications/impact-tokens.pdf
88 IXO Foundation White Paper, retrieved May 20, 2022, https://www.ixo.world/white-paper
89 *Ibid.*

The data must fulfill predetermined “proofs of impact” so that service providers can claim success and investors can receive their financial returns.

In addition to using this data to verify the end state of a project, the data continuously feeds an internal prediction market between project stakeholders that dynamically adjusts parameters, such as interest payments tied to owning the impact token. Called alphabond, this mechanism aims to increase the impact token’s sophisticaton as a financial instrument.

The IXO protocol further enables monetization of the data generated by the impact token, leveraging blockchain-based data marketplaces, such as the one offered by the Ocean protocol. Ocean Protocol[90], founded by MIT's Bruce Pon in 2017 and now based in Singapore, is associated with the World Economic Forum and the MIT Media Lab.

Ocean Protocol, through ERC-20 tokens, is an ecosystem that allows any organization to share data while maintaining control and ownership over it, including through artificial intelligence algorithms based on federated learning[91].

These datasets are available on the Ocean Market, where they can be purchased and then consumed or sold. Through the Ocean Protocol, each data service is represented by a unique data token, which is used to “wrap” a dataset or compute-to-data service - allowing third parties to perform operations on that data without leaving the publisher's secure enclave[92].

The **Ocean protocol**, like the IXO protocol, is the beginning of this new data economy whose access, exchange, and monetization are based on Web 3.0.

Just like the **Proof of Impact** project. Founded in 2019 in Amsterdam, The Netherlands, Proof of Impact is headquartered in San Francisco, USA. Fleur Heyns, co-founder of the startup explains the problem the company is addressing in these terms: “*How do companies report on the impact they have? How can consumers discern which companies are having a positive impact on the environment from those that merely claim to be making an impact, as part of an insidious and pervasive trend of impact washing? How can investors compare one company with another when it comes to assessing their value through a holistic lens?*”[93].

90 Ocean Protocol: https://oceanprotocol.com/
91 “Rather than centralizing data to train a central algorithm, federated learning consists in training an algorithm on the machine of the users of an application and then sharing the learnings thus achieved” in “Apprentissage fédéré : une nouvelle approche de l’apprentissage machine”, Yann Bocchi, August 11, 2021, https://blogs.letemps.ch/yann-bocchi/2021/08/11/apprentissage-federe-une-nouvelle-approche-de-lapprentissage-machine/
92 Ocean Protocol: https://coinmarketcap.com/fr/currencies/ocean-protocol/
93 “Abbreviated White Paper — Proof of Impact”, Fleur Heyns, January 26, 2021 https://medium.com/proofofimpact/abbreviated-white-paper-proof-of-impact-89096c307204

Proof of impact's value proposition is thus to capture data at the source from a repository of impact metrics from companies via the Proof of Impact platform.

"*As this data is pushed to POI, each output unit is automatically verified, using algorithmic techniques for ensuring the data is unique and non-anomalous. Once data submissions are verified, they are minted to the blockchain, representing an "*impact token*" that is secure, immutable, and auditable.*"[94]

The company plans to interface its proprietary platform with the Ethereum blockchain and a second-tier blockchain.

94 *Ibid.*

Hiveonline was founded in 2016 in Copenhagen, Denmark by Sofie Blakstad to focus, as of 2019, on rural African markets. Hiveonline "*collects digital assets such as contracts, payments, photographs, certificates, and guarantees, then stores them in a blockchain accessible to all participants in the system.*"

The company, which is heavily involved with NGOs and international organizations, including the United Nations Development Programme (UNDP), the United Nations Capital Development Fund (UNCDF), Save the Children, and Mercy Corps, has developed three complementary services, all based on distributed registries, in response to the observation that "*everywhere, small businesses face the same problems in establishing trust, accessing credit and reaching markets efficiently*"[1].

The first service is the dematerialization of "cash and voucher assistance" (CVA), which is widely used by humanitarian aid, accounting for $5.6 billion in 2019, twice as much as in 2016, or 17.9 percent of total humanitarian aid[2].

Despite this rapid expansion, cash and voucher assistance faces a number of challenges, including the cost of implementation when distributing physical cards or paper vouchers and when a traditional financial partner is involved (bank, local bank, telecom operator), which charges large commissions on each money movement.

Moreover, it is complex to know who really benefits from the assistance. In the field, Hiveonline also explains that "*many retailers do not accept vouchers because they cannot be sure of the refund*"[3].

The system offered by Hiveonline dematerializes assistance into cash and vouchers that take the form of tokens generated via Hiveonline's blockchain, significantly reducing distribution time and transaction costs while improving tracking, evaluation, and auditability of the assistance program.

The second service deployed by Hiveonline, vsla.online, concerns "*access to affordable credit, insurance and savings for communities in the informal economy.*"[4] According to Sofie Blakstad, "*in Niger, there are more people, mainly women, in informal savings networks - 800,000 - than in the entire formal banking*

1 "Sustainable Digital Finance for the next billion", Hivenetwork, Hivenetwork website, retrieved May 10 2022, https://www.hivenetwork.online/
2 "The State of the World's Cash 2020", José Jodar, Anna Kondakhchyan, Ruth McCormack, Karen Peachey, Laura Phelps, Gaby Smith, CalpNetwork website, Jul 23 2020, calpnetwork.org.
3 "Sustainable Digital Finance for the next billion", Hivenetwork, Hivenetwork website, retrieved May 10 2022, https://www.hivenetwork.online/
4 "A digital solution for savings groups: vsla.online", Hive Network, https://www.hivenetwork.online/rethinking-vsla-community-finance/

system, which has only 700,000[5]*".*

The typical Hiveonline user in Niger is "*a woman who has only attended one year of school and cannot read or write, has never used technology, has no access to electricity or running water, and supports five to 15 family members by selling products locally*."[6]

The service provided by Hiveonline consists of the dematerialization of programs such as Village Savings and Loan Associations (VSLA), which can also exist in other forms such as Savings and Internal Lending Communities (SILC) or tontines, associations that bring together members of a clan, family, neighbors or individuals, who pool goods or services for the benefit of everyone in turn[7].

These communities, using Hiveonline's tools, record all their transactions, simplifying record keeping, ensuring the security of operations, and guaranteeing the identity of each member. These communities then develop a form of financial reputation: "*As these transactions accumulate and are recorded on Hiveonline's blockchain, savings groups enhance their reputation and creditworthiness by creating a digital record of commitments made and kept, including loans and repayments at the group and individual member level*"[8].

This financial reputation then allows these communities to connect with microfinance financial institutions, which are more likely to lend, as transparency reduces the cost and risk of lending to these informal enterprises and savings groups, which can then diversify their livelihoods and increase their access to credit and finance.

Finally, Hiveonline's third service, myCoop.online[9], promotes the grouping of farmers into cooperatives to facilitate their access to finance. According to Sofie Blakstad, "*Smallholder farmers are trapped in generational poverty because they cannot access credit to improve their crop yields. Markets are inefficient and dominated by middlemen. Yet 70% of Africa's arable land remains uncultivated, and the potential for growth is enormous. Agricultural businesses face many challenges, including cash flow, seasonality, loss of profits to middlemen and natural disasters*".[10]

In addition to greatly simplifying the administrative and financial management of an agricultural cooperative, the way myCoop.online works is as follows:

5 *Ibid.*
6 *Ibid.*
7 Définition du philosophe et sociologue Zygmunt Bouman.
8 "Building Credit History through Financial Reputation ", Hivenetwork, Hivenetwork website, retrieved May 10, 2022, https://www.hivenetwork.online/financialreputation/
9 "Enhancing agricultural cooperatives and rural livelihoods: myCoop.online ", retrieved May 13, 2022, https://www.hivenetwork.online/agricultural-cooperatives/
10 "Solve, an initiative of the Massachusetts Institute of Technology (MIT): hiveonline, Sustainable digital finance without a phone", retrieved May 13, 2022, https://solve.mit.edu/challenges/digital-inclusion/solutions/48750

Hiveonline first creates a unique identity for the farmers of the association or cooperative (see chapter "Identity & Ownership"). Farmers then publish crop forecasts, plant and deliver their crops, with all transactions being recorded via the myCoop.online service.

A reputation score is generated, at the individual and cooperative levels, based on whether or not commitments are met. Financial institutions, buyers, and support organizations view, through online dashboards, "*candidates for loans, crop purchases and farm input distribution based on their history of reliable behavior*"[11]. A farmer will then be able to more easily access loans, including for the purchase of farm inputs to start a new crop.

Hiveonline has partnered since 2019 with the Mozambican Association for the Promotion of Modern Cooperatives (AMPCM) and the Royal Norwegian Society for Development to develop a digital solution for cooperatives.

The first experiments, conducted to support small farmers working for the cashew industry, have since expanded to other crops in Mozambique, with the same goal of professionalizing agriculture and improving yields for small farmers.

Challenges identified by Hiveonline include "*lack of credit history or financial reputation to prove to lenders that they are reliable, inefficient markets, and low productivity due to lack of access to affordable agricultural inputs*"[12].

11 *Ibid.*
12 Hive Network, Agricultural Cooperatives: https://www.hivenetwork.online/agricultural-cooperatives/

ISSUES AND QUESTIONS

The diversity of issues and questions raised by the loss of the States' monopoly on money, or at least on the transfer of value, reveals the extent to which society as a whole is making a transition from an old model that is out of breath to a new model that is still in the making.

The trigger of this transition coincides with the invention of the universal computer in the 1950s, i.e., of computing, then of the Internet network in the 1970s and its services such as the web or email, and then of their entanglement for less than 15 years in a contemporary and decentralized version, in the way that the Ethereum blockchain defines itself: "*a global computer that anyone can program and use as he or she wishes. This computer is always on, it is very secure, and everything that is done using this computer is public*"[1].

Countless questions remain about every use and experimentation that develops around blockchains and their tokens.

Cross-border remittances, peer-to-peer payments and micro-payments, so-called decentralized finance that allows borrowing, saving, and investing without a banking institution, complementary local currencies of a new kind, decentralized parametric insurance, universal income, crowdfunding, inclusive finance, impact verification or impact investment, it seems that the diversity of initiatives shows the emergence of a phenomenon that is programmed to last.

The appeal of sending cross-border funds from person to person using crypto-currencies is undeniable: almost instantaneous transactions, reduced fees, as well as the assurance of owning one's funds.

The question then arises as to how bridges could develop between the real economy, whether informal or formal, whose exchanges would rely on this new form of programmable money.

1 "Qu'est-ce qu'Ethereum ?", Simon Polrot, Ethereum France, February 14, 2016, retrieved May 17, 2022. https://www.ethereum-france.com/quest-ce-que-lethereum/

Since crypto-currencies are peer-to-peer electronic currencies, the first obstacle to their adoption is the ability of everyone to use them: how to download a wallet, how to initiate a transaction, and how to receive or send funds in peer-to-peer.

Are crypto-currencies used as an instrument to escape the devaluation of a local currency or as an alternative currency, usable locally because it is accepted as a means of payment, especially in satoshi*?

Is decentralized finance reserved for those who can afford it but do not have access to financial markets, or will it expand its audience?

What about hacking or the collapse of shaky crypto-currencies like the Terra USD, which went from one dollar to a few cents in a few hours in May 2022, causing the pure and simple disappearance of the savings and investments of small holders in Pakistan, India, Argentina or Nigeria?[2]

Are complementary local currencies and financial inclusion currencies just an opportunity to improve the efficiency of these monetary tools, or will they become tools of crypto surveillance, for better or worse?

In addition to these questions, which are specific to each of these uses, there are other cross-cutting issues, such as the energy impact of the blockchains used, their ability to scale up as they are adopted, the security of smart contracts and decentralized applications, not to mention the legal and regulatory uncertainty that the guardians of the traditional financial system are placing on these peer-to-peer electronic currencies.

No one knows yet the exact trajectory of these blockchains, nor how they will meet their audience, except that their adoption rate is steadily increasing, especially in countries at the margins of the traditional financial system and whose citizens are excluded from society because they have no bank account or identity.

2 “Le Krach a balayé les petits porteurs”, Leo Schwartz et Abubakar Idris, *Rest of World* in *Courrier International*, n°1649 June 9, 2022.


HEALTH

HEALTH

Number of projects in the directory: 148

Number of active projects: 71

Name of active projects: Aenco ; Amchart ; Astri ; Avyantra ; Betterpath ; BitMark ; BlockMedx ; Bowhead Health ; BurstIQ ; CareChain ; Change Healthcare ; Citizen Health - Citizen DAO ; ConsilX ; CoverUS ; dClinic ; Decent (healthcare) ; DNAtix ; Doc.ai ; Embleema ; Encrypgen ; Factom ; “FarmaTrust” ; Gainfy ; Genecoin ; Geneyx ; GenoBank ; Grapevine ; Guardtime & Estonia eHealth strategy ; Hashed Health ; Health Verity ; Health Wizz ; Healthcoin.nl ; HIE of One ; HIT Foundation ; Humanscape ; intiva ; Iryo ; iSolve ; Kidner ; KimboCare ; Longenesis ; lunaDNA ; Lynx ; MediBloc ; MedicalChain ; MediLedger ; Meditect ; Medrec ; Medvice ; “MedX Protocol” ; Modum ; Molecule ; MyHealthMyData ; Nano Health ; Nebula Genomics ; Open Health Network ; Patientory ; Peer Ledger ; PharmaTrace ; PointNurse ; PPPHealth4All ; Prescrypto ; Quanti Health ; Ribbon blockchain ; Shivom ; Sicpa - Covid pass ; SkyChain Global ; Spiritus ; Statwig ; Zenome ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

The healthcare industries, which include the pharmaceutical industry, biotechs, medtechs and private and public healthcare entities, have taken up digital technology through six major projects, which the Fondation de l’Avenir describes as follows:[1] *“**Health information systems** enabling better coordination of care within a healthcare establishment (Hospital Information Systems or HIS, Electronic Patient Record or DPI, etc.) or a healthcare territory (Shared Health Information Systems). **Telemedicine** offering remote care possibilities: teleconsultation, tele-expertise, remote monitoring, remote assistance, and medical regulation. **Telehealth** integrating monitoring and prevention services for individuals with a primary objective of well-being (connected objects, mobile self-measurement applications, web platforms, etc.). **Technological devices focused on patients or the general public**: m-health or m-health (M for Mobile) mobile health applications, web health applications, connected objects, social networks (patient communities), health information portals, etc. **Technological devices focused on healthcare providers such as healthcare**

1 Fondation de l’Avenir, Foundation for applied medical research, recognized as a public utility.

***institutions and professionals**: internal HIS, shared information systems, on-board information systems (e.g. SMUR), telemedicine devices, etc. **Technological devices centered on insurance companies, public regulators and industry**: generic customer relationship management (CRM) tools as well as datamining (internal data) or big data (external data) allowing the collection, storage and algorithmic processing of massive health data".*

However, the overwhelming majority of the information systems used by all of these actors are not interoperable and patient data is centralized and replicated within each institution, copied again in each of the information systems that request its transmission, and sometimes even gathered again in mega platforms such as the "Health Data Hub" in France, deployed in 2021,[2] which clearly poses problems of sovereignty when we know that the hosting provider is American.[3] Yet health data are by nature personal, and are said to be **sensitive data** because they reveal information related to a person's health.

The use of distributed blockchain registries would, according to their promoters, enforce the interaction of healthcare organizations with one or more decentralized identity systems, which would result in **the reappropriation of health data by the patient who would decide the sharing** and, above all, have the assurance of the confidentiality of their health data or at least the assurance of being the one who authorizes or refuses the use of their personal data by others (*if hospital patient data were not administered in silos by each institution, ransomware and cyberattacks would lose considerable interest).*

The use of distributed registries would also greatly improve **access to health data among disparate stakeholders**, sometimes with conflicting interests. The implementation of such registries would also allow for a reduction in healthcare costs, through the streamlining and optimization of operational, administrative and financial processes.

The 144 blockchain initiatives that we have identified in the healthcare field are organized around these promises, but some ten years after the launch of the first projects, it is clear that many of them have disappeared (77 out of 148 projects are no longer active), that others are only blockchain in name, and that, in the end, only a few use cases remain.

2 All of the French people's health data will indeed be hosted in France, but by an American operator, which under the *Cloud Act* could be forced by the American justice system to transfer all of this personal information to the United States. "The Great Divide between Gaia-X and the Health Data Hub", Jacques-André Fines Schlumberger -N°54bis-55 Fall 2020 https://la-rem.eu/2020/12/le-grand-ecart-entre-gaia-x-et-le-health-data-hub/

3 "The Great Divide between Gaia-X and the Health Data Hub", Jacques-André Fines Schlumberger -N°54bis-55 Fall 2020 https://la-rem.eu/2020/12/le-grand-ecart-entre-gaia-x-et-le-health-data-hub/

For Anca Petre, founder of 23 Consulting, *"projects do not succeed because they require working in consortium. This is the very basis of the technology, but it raises questions of intellectual property, business model, and governance, not to mention regulatory issues"*.[4] Blockchains, in the field of health, highlight that the **issues facing organizations and patients are primarily political and less and less technical**. Anca Petre emphasizes *"technology is no longer a subject, it is mastered. The same goes for use cases. It's the governance and implementation that are the problem today"*.

In January 2021, a study[5] conducted by researchers at SingHealth Polyclinics in Singapore identified ten operational blockchain projects in healthcare among the 8,326 public blockchains listed on coinmarketcap.com.

A healthcare company launching a blockchain on its own makes no sense. A consortium of healthcare companies operating a common public blockchain makes more sense. In this sense, **PharmaLedger,** bringing together 29 healthcare organizations, is a promising initiative,[6] but a mega-consortium of healthcare companies that relies on a decentralized identity system, public blockchains and private sidechains* does not yet exist.

However, even if the implementation of distributed registries applied to the health domain is still in its infancy, the experiments and pilot projects conducted since 2010, as well as a certain enthusiasm from the scientific community, show four main areas of experimentation:

1. The management of health data and patient medical records, known as "shared medical records" (DMP) in France, or Electronic Health Records (EHRs) elsewhere in the world, from the United States to Brazil, via China, Denmark and India.
2. Research on new drugs, clinical trials, and precision medicine.
3. Improving the traceability of medicines.
4. Optimizing health insurance coverage, particularly through the use of smart contracts*.

Depending on how they are designed, these projects are in line with the third Sustainable Development Goal, which aims to *"ensure the health and well-being of all, by improving reproductive, maternal and child health, reducing major*

4 "Blockchain in pharma: promises soar, use cases remain", Leo Caravagna, TicPharma, January 5, 2021, ticpharma.com,

5 "Commercially Successful Blockchain Healthcare Projects: A Scoping Review.", Fang, H. S. A, Blockchain *in Healthcare Today*, *4*. 2021, https://doi.org/10.30953/bhty.v4.166

6 Sponsored by the Innovative Medicines Initiative (IMI) and the European Federation of Pharmaceutical Industries and Associations (EFPIA) as part of the Horizon 2020 program, PharmaLedger is a 36-month project, beginning in 2020, that brings together 12 global pharmaceutical companies and 17 public and private entities, including technical, legal, and regulatory agencies, universities, research organizations, and patient-representative organizations.

communicable, non-communicable, environmental and mental diseases. These health challenges can be met by putting in place prevention systems aimed at reducing deviant behaviors as well as any health risk factors, ensuring universal access to medical coverage and health services, supporting research and development of vaccines and medicines, and improving health risk management in developing countries".[7]

According to the United Nations Development Programme (UNDP), *"400 million people lack access to basic health services, 40% of the world's population lacks social protection, and 1.6 billion people live in fragile environments where lack of access to basic health services is a major barrier"*.[8] Target 3.8 explicitly aims to ensure that *"everyone has access to universal health coverage, including protection against financial risks and access to quality essential health services and to safe, effective, quality and affordable essential medicines and vaccines".* Target 3.b aims to *"support research and development of vaccines and medicines for communicable and non-communicable diseases that primarily affect people in developing countries, and provide access to affordable essential medicines and vaccines (...)".*[9]

These are a few of the blockchain initiatives at work in the areas of healthcare data management, research and drug traceability.

Patient data

In today's healthcare system, patients disseminate their personal data every time they interact with the healthcare sector: hospitals, pharmacies, networks, physicians, etc.

Even though health data, by nature personal, is called **sensitive data** because it reveals information related to a person's health, the model of centralizing data, either internally on servers or in remote hosting services has always been the norm.

However, health data is intimately linked to the notion of digital identity (see chapter "Identity and Ownership") and, more precisely, to the notion of decentralized digital identity, supported by distributed registry technologies and the standardization of technical standards supported in particular by the W3C.

In 2009, at the same time that Satoshi Nakamoto released the first version of the Bitcoin software on the P2P Foundation website,[10] Catherine Quantin, then at the Biostatistics and Medical

7 Sustainable Development Goal 3: Empower people to live healthy lives and promote well-being at all ages, Ministry of Ecological Transition, agenda-2030.fr
8 United Nations Development Programme, Sustainable Development Goal 3: Good Health and Well-Being undp.org
9 *Ibid.*
10 P2P Foundation Forum Posts https://www.bitcoin.com/satoshi-archive/forum/p2p-foundation/#selection-13.1-2.3

Informatics Department of the Regional and University Hospital Center of Dijon, France, was already concerned as follows:

> *"The fact that all information is contained in a single place is a dream that testifies to an old vision of organization where centralism was the only way, whether it was inspired by French-style Jacobinism or the democratic centralism dear to the supporters of collectivist systems. However, several decades ago, the public authorities became aware of* ***the danger intrinsically linked to this central organization, which exposes everything to loss if it is destroyed****. How can we not imagine that all the hackers in the world would not take it as a challenge to break into the national bank of patients' medical records to consult them or, worse, change the information they contain? How can we not fear that terrorists of all convictions would not see this as an extraordinary opportunity to destabilize an entire country by attacking an area to which citizens attach great importance: their health and the confidentiality of the information that goes with it? How can we accept the risk that such an organization poses for the privacy and security of individuals if the State that sets it up deviates from the paths of democracy and respect for individual freedoms?"*[11]

The fundamental contribution of blockchains in the field of digital identity, and therefore of health data, is to **reverse the current model based on the centralization of data managed by an organization, to a model based on the verifiability of attestations controlled by an individual**. While the current model gives all the power to the organization that "manages" the health data of individuals, the decentralized digital identity model gives back to the individual the opportunity to decide who accesses his or her personal information. This, ultimately, corresponds to the very spirit of the General Data Protection Regulation (GDPR) applicable in all 27 European Union member states since May 25, 2018, which lays down, among other things, the principles of an individual's "explicit" and "positive" consent to the use of his or her personal data, as well as the right to erasure of that same data. This paradigm shift also allows third parties to access people's health data while guaranteeing its confidentiality and use.

The promise of blockchain initiatives is to put patients back in control of their personal health data. **Medical Chain,** founded in 2017 in London, UK, promises a system *"that gives end users around the world a secure platform to manage and transfer their health data, to gain*

11 "Decentralized management of patients' medical documents. A search and data access system", Quantin Catherine, Coatrieux Gouenou, Fassa Maniane *et al*, *Document numérique*, 2009/3 (Vol. 12), p.23-35, https://www.cairn.info/revue-document-numerique-2009-3-page-23.htm

actionable insights to improve health and wellness outcomes".

Patientory, founded in 2015 in Atlanta, USA promises to *"give patients control over their medical data, empowering them to share the most comprehensive and complete version of their record, with every organization in their medical network".*

My Health My Data, a European consortium of some 15 partners, funded with €4 million from the European Horizon 2020 program between 2016 and 2019 aimed to *"secure patient data, reduce 'by design' the risk of identity theft and privacy breaches, and introduce a new way of sharing private information by empowering its primary owners, the patients".*[12]

A subsidiary of the be-ys group, the French company be-studys[13] has been marketing **ProRegister** since August 2021 as an *"industrialized version of the 'My health, my data' pilot*", currently used by four European hospitals in Rome, Berlin and London and managing the health data of 81,000 patients. David Manset, managing director of be-studys details the project as follows: *"The healthcare institutions are equipped with software to make available the data of patients who give their consent. This software indexes and pseudonymizes the data. It creates an 'identity card' for the data and records it in the blockchain, which does not contain any personal data* (...) *Each data provider is considered a trusted third party. The blockchain allows them to reference their data without being in conflict with the RGPD. Access to the data is via the 'My health, my data' portal. The access request creates a smart contract* that allows for the provision of data and traceability of all operations via an API".*[14]

However, most of these initiatives, based on private blockchains, mostly permissioned, are more about improving and optimizing existing systems rather than developing new, truly decentralized models in which individuals have full control over their health data. Public blockchain projects in the health field that address an entire ecosystem or a specific domain are complex to implement, mainly because of the diversity of stakeholders and their sometimes conflicting interests.

In a completely different field, the sequencing of the human genome has many applications in medicine, molecular biology, medical genetics, and microbiology in order to make diagnoses, identify genetic mutations or detect the genetic predisposition of a person to certain diseases.

12 "My Health - My Data", European Commission, retrieved May 16 2022, https://cordis.europa.eu/project/id/732907
13 "Be-studys wants to involve patients in medical research", Sylvie Jolivet, Les Echos, May 9, 2019, https://www.lesechos.fr/pme-regions/innovateurs/be-studys-veut-associer-les-patients-a-la-recherche-medicale-1017207
14 "Blockchain in pharma: promises soar, use cases remain", Ticpharma, retrieved May 16 2022, https://www.ticpharma.com/story/1498/blockchain-dans-la-pharma-les-promesses-s-envolent-les-cas-d-usage-restent.html?search=MHMD

The Human Genome Project, the first sequencing of the human genome, was launched in 1988, completed in 2003 and cost $2.7 billion.[15] Today an individual can have their entire genome sequenced for $100.[16] In 2015, researchers estimated that between 100 million and 2 billion human genomes could be sequenced by 2025.[17]

But *"who has access to the data and how do we ensure its security? How can the data be used and shared responsibly without losing the benefits of sharing for research and (future) patients?"* asks Mohammed Alghazwi, a researcher at the University of Groningen in the Netherlands.

The company 23andMe is a perfect example of the potential pitfalls of centralizing people's health data in a single entity. Founded in 2006 in California, 23andMe is a U.S. biotech company that offers individuals an analysis of their genetic code. In 2018, the startup opened up its capital to healthcare company GlaxoSmithKline,[18] to the tune of $300 million, also allowing the pharmaceutical giant to get its hands on its customers' personal genomic data *"for medical research purposes to develop new drugs".*[19]

No one knows what has happened since, whether any data has been leaked and how 23andMe customers' genetic data has been used by GlaxoSmithKline. One thing is certain: none of the company's customers were able to object to the use of their health data by the pharmaceutical giant.

The very nature of these services, which entrust personal genomic data to a single entity that manages the data centrally, is increasing risk.

In the United States, in 2021 alone, more than 40 million medical records were publicly exposed.[20]

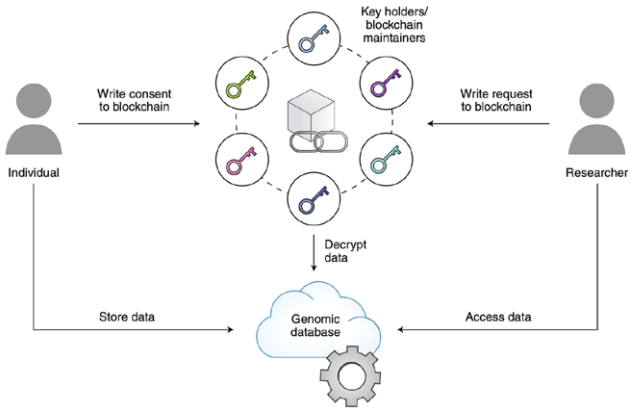
Lawmakers will always be behind the curve, and the risk of cyberattacks will always increase in intensity. Robert Kain, co-founder of Luna DNA Inc,[21] a community-based health and DNA research platform, explains that

15 "Business, ethics, legality... Le séquençage de l'ADN en questions", Alexandre Léchenet, Le Monde, August 18, 2014, https://www.lemonde.fr/les-decodeurs/article/2014/08/18/le-sequencage-du-genome-comment-ca-marche_4472313_4355770.html
16 "Chinese biotech launches first $100 genetic test", Fabrice Delaye, February 27, 2020, Heidi.news, heidi.news/
17 "Big Data: Astronomical or Genomical?", Stephens ZD, Lee SY, Faghri F, Campbell RH, Zhai C, Efron MJ, et al, PLoS Biol, 2015, https://doi.org/10.1371/journal.pbio.1002195
18 "23andMe and Other Sites are Selling Users' Genetic Data: How Safe is Your DNA?", Justin Roberti, Feb 28 2021, https://hackernoon.com/23andme-and-ancestrycom-are-selling-users-genetic-data-how-safe-is-your-dna-x64k3330
19 "A Major Drug Company Now Has Access to 23andMe's Genetic Data. Should You Be Concerned?", Jamie Ducharme, Time, Jul 26 2018, https://time.com/5349896/23andme-glaxo-smith-kline/
20 "The biggest healthcare data breaches of 2021", Kat Jercich, November 16, https://www.healthcareitnews.com/news/biggest-healthcare-data-breaches-2021
21 "Database shares that transform research subjects into partners", Kain, R., Kahn, S., Thompson, D. *et al.* ,

in the United States, *"the Genetic Information Nondiscrimination Act protects individuals from discrimination by employers and health insurance companies. But it does not apply to life and disability insurance, and does not protect against discrimination in other areas, such as education and housing. In the future, other potentially troubling uses of genomic data may be developed. For example, personal genomic data could become valuable for targeted advertising".*

Encrypgen,[22] **Zenome,**[23] **DNAtix**[24] and **Nebula Genomics** are some of the startups offering an alternative model to that of private companies like 23andMe and propose that users retain control of their genomic data, and even profit from it if they wish to share it with the health industry. **Nebula Genomics**, founded in 2016 by Dawn Song in San Francisco, USA, is a biotech company that offers individuals the sequencing of their genome with indecipherable data and gives their customer control over who can access it, depending on the purposes their customer chooses, revokes, and rekeys.

The startup depends on Oasis Labs, which develops the Oasis Network[25] (ROSE), founded by Dimitar Dimitrakiev, Phillipp Grenzebach and Jeremias Grenzebach in March 2017 in the Netherlands. The Oasis Network (ROSE) is a top-level blockchain, based on the Cosmos blockchain (ATOM), focused on privacy and with a consensus mechanism based on proof of ownership*.



Access to genomic data is *"controlled by multiple independent parties who hold fragments of a shared encryption key. In addition, these parties maintain a blockchain that immutably and transparently stores data access requests and user consent".*[26]

The Oasis network is built for the open finance and verifiable data economy using the Cosmos SDK*, which has an architecture similar to that of

Nat Biotechnology 37, 1112-1115, 2019, https://doi.org/10.1038/s41587-019-0278-9
22 Founded in New York, USA in 2016.
23 Founded in Moscow, Russia in 2017.
24 Founded in Ramat Gan, Israel in 2018.
25 "Ensuring auditability and immutability of actions with a distributed network.", Oasis Labs, Retrieved 16 May 2022, oasislabs.com
26 "Data privacy in the age of personal genomics", Kain, R., Kahn, S., Thompson, D. *et al* , Database shares that transform research subjects into partners, *Nat Biotechnology* 37, 1112-1115, 2019, https://doi.org/10.1038/s41587-019-0278-9

the **Avalanche** or **Polkadot** public blockchains, connecting several different blockchains within the same ecosystem. Nebula Genomics uses the Oasis Labs network to secure its customers' data, and thus give them control over it.[27]

Zenome, founded in Moscow, Russia in 2017 uses the Ethereum public blockchain and smart contracts* to connect people who want to share and sell their genome sequencing to third parties, including researchers. The service provided by Zenome is twofold: on one hand, it allows anyone to provide their computer's resources, whether disk space or processor time, for the needs of distributed storage and analysis of genetic data and get a reward in ZNA token and, on the other hand, it ensures the security of the genomic data of its users.

Alongside the offerings of these startups, non-commercial genomic research applications provide solutions for "*sharing, processing/analysis, secure storage, access control, and logging access to genomic data*[28]" based on the intrinsic characteristics of blockchains: "*immutability, decentralization, and access/use control*[29]".

According to the study "Blockchain for Genomics: A Systematic Literature Review",[30] published in November 2021 and source of the image below, of the 13 commercial enterprises identified by the researchers, the majority of distributed ledgers rely on private permissioned blockchains, with 31% developed on Multichain[31] and 27.6% on the public blockchain Ethereum.

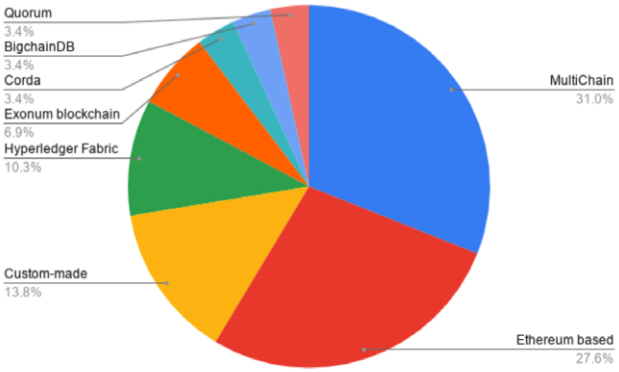


Fig. 8. Blockchain platforms used in genomic data applications

27 "Take Control of your Genomic Data", Nebula Genomics, Retrieved May 16, 2022, nebula.org
28 "Blockchain for Genomics: A Systematic Literature Review.", Alghazwi, M., Turkmen, F., van der Velde, J., & Karastoyanova, D., 2021, *arXiv preprint arXiv:2111.10153*.
29 *Ibid.*
30 *Ibid.*
31 MultiChain is a blockchain platform for building and deploying private or permissions-based blockchain networks. MultiChain is open source under the GPLv3 license, available on Github, and also offers commercial licensing and support. "MultiChain For Developers", Multichain, Retrieved May 16 2021, https://www.multichain.com/developers/

Clinical & Research

The report *"Blockchain technology applications in healthcare: An overview"*, published by Indian researchers in September 2021, suggests that, in the field of clinical trials and research, blockchains could *"solve the problems of result modification and data mining, ensure the transfer of permanent and time-stamped clinical trial reports and results, thus reducing the cases of scams and errors in clinical trials, and solve the problems of false results".*[32]

This transition has been accelerated by the global Covid-19 pandemic and, according to the professional information website mind Health, *"to reduce patient recruitment times, open access to clinical trials to a greater number of patients, facilitate the collection of consent, simplify the conduct of trials, increase patient loyalty in the study or use software and digital tools to improve the supervision of studies... These uses are multiplying and contributing to the development of decentralized trials".*[33]

Health professionals now speak of *"decentralized clinical trials"* or *"real-life health data"*, meaning that participants in a clinical trial no longer physically travel to research centers but are monitored remotely, possibly with travel to a local health professional or even directly from their home.

French-American startup **Embleema Health Network** has been developing several services since 2018 based on a distributed registry to share health data for research against chronic and rare diseases, bringing together patients, medical communities, scientists, industry and health authorities.

In particular, Embleema's IT tool enables the management of patient consent to share their health data, so that they can participate in paid clinical trials. From a technical perspective, Embleema has been developed on Hyperledger Fabric, a private permissions-based blockchain with all nodes managed by the company. It now works for the Food and Drug Administration (FDA) in the United States, the U.S. administration responsible for authorizing the marketing of drugs in the territory.

In a statement reported by mind Health, Robert Chu, the founder of Embleema, explains the purpose of the $6 million, three-year contract: *"The goal is to build a research database containing all annotated genomic information on covid-19 variants and, in general, on all pathogen variants (influenza, flu, HIV, hepatitis B, salmonella).*

32 "Blockchain technology applications in healthcare: An overview.", Abid Haleem, Mohd Javaid, Ravi Pratap Singh, Rajiv Suman, Shanay Rab, International Journal of Intelligent Networks, Volume 2, 2021, Pages 130-139, https://doi.org/10.1016/j.ijin.2021.09.005.

33 mind Health is a professional information service dedicated to the transformation of the healthcare industries, published by Frontline MEDIA, which is supported by the Île-de-France Region, as part of the PM'up program, and by the Institut pour le Financement du Cinéma et des Industries Culturelles (IFCIC), "Presentation of Mind Health", Mind Health, Accessed on May 16, 2020, menshealth.fr

Through the Embleema platform, the FDA will share this data with all researchers worldwide. When a pharmaceutical company uses reference data on our platform, the FDA knows that it is of regulatory quality and that it meets high quality criteria that include the provenance and auditability of all processing performed on it. The entire data processing pipeline must comply with international standards as much as possible. Our algorithms guarantee the veracity of the analysis. In addition to avoiding fraud or falsification, our system accelerates the regulatory approval of health products for all these pathogens and their availability to patients".[34]

Nevertheless, a private blockchain with authorization and whose nodes are all managed by a company corresponds to the optimization of a database rather than to the implementation of a universal common language allowing to both guarantee the confidentiality of people's data and to allow the mass processing of these same health data.

This process nevertheless has the merit of optimizing a *"costly, slow and manual* collection*, monetized by intermediaries"* explained Alexis Normand in 2018, then in charge of the consortium at Embleema, citing the example of the cost of reconstituting a complete medical record of a person with cystic fibrosis, which amounts to 10,000 dollars, or Parkinson's disease, which amounts to 20,000 dollars.[35]

ConsilX, founded in 2017 in Singapore, with an office in India, also bills itself as a *"decentralized clinical trials platform"*,[36] based on *"real-life health data"*. The platform, called LifeLedger™, proposes a *"digital consent"* solution, activatable onsite or remotely, patient-wearable health data measurement devices, electronic diaries and questionnaires, and a telemedicine module to provide doctor-patient communication, all managed by a blockchain and smart contracts to *"notarize the data"* and allow the patient to share or not to share their health data. Like all the others, this project uses a private blockchain.

Molecule, founded in Berlin, Germany in 2018, is *"a marketplace for funding, collaboration and transaction of early stage biopharmaceutical research projects".*[37] Researchers present their research projects, find investors and collaborators and develop their research projects. Investors and funds select biopharmaceutical research projects and finance those that catch their attention.

The infrastructure of the Molecule platform is built on Ethereum allowing researchers and investors to have full access to the decentralized finance ecosystem (DeFi).

34 "A totally virtual clinical trial is a hundred times faster than a traditional study", Robert Chu (Embleema), Camille Boivigny, Mindhealth, October 18, 2022, mindhealth.fr.
35 "Embleema puts blockchain to work for pharmacovigilance", Wassinia Zirar, TicPharma, 12 October 2018, https://www.ticpharma.com/story/732/
36 "Platform Features", Consilx, Retrieved May 16 2022, https://www.consilx.com/platforms-overview
37 What is Molecule? https://docs.molecule.to/documentation/introduction/what-is-molecule

The catalog of research projects to be funded is public.[38] For example, the program *"discovering new activators of autophagy"*[39] (autophagy is a process of self-digestion that consists of degradation of intracellular components by the lysosome) carried out by the Professor of Molecular Cell Biology Viktor Korolchuk of the University of Newcastle in England received $285,000 in funding. The research project is associated with NFT, which corresponds to the investment and exploitation of intellectual property rights.

Paul Kohlhaas, co-founder of Molecule explains that this new approach allows *"the combination of non-fungible tokens (NFT), a new automatic exchange infrastructure (AMM), and governance structures (DAO) to reinvent intellectual property and the financing of these assets"*.[40] As of June 2022, Molecule references 250 research projects for funding and three decentralized autonomous organizations (DAO*) bringing together 4500 people and capitalizing over $10 million.[41]

Drug Traceability

According to the World Health Organization (WHO),[42] one in ten medicines in circulation worldwide is of "*inferior quality or falsified"*, one in four in developing countries. The falsification of medicines now concerns all major therapeutic classes, including drugs, vaccines and in vitro diagnostic products. According to WHO, *"low- and middle-income countries, those in areas of conflict and civil unrest, and those with weak or non-existent health systems bear the brunt of the problem of substandard or falsified medical products"*.[43]

Several solutions have already been devised in the past to combat falsified medicines: printing a hologram on a drug package, which can however be easily counterfeited; mass serialization, via a radio frequency identification (RFID) system to assign unique identifiers to packages, but which, in addition to being costly, can also be easily counterfeited; mass encryption technology, which requires all actors to use the same technology, which seems complicated to implement; and the European Union's Falsified Medicines Directive (FMD), which aims to make it mandatory in Europe to identify medicines as they move through the supply chain.

38 Discover Research Projects Invest in biopharma researchers and their work https://discover.molecule.to
39 Discovering Novel Autophagy Activators https://discover.molecule.to/projects/cl3vghfw7005209lcesv415qq
40 An Open Bazaar for Drug Development: Molecule Protocol Paul Kohlhaas Jun 11, 2021 https://medium.com/molecule-blog/an-open-bazaar-for-drug-development-molecule-protocol-a47978dd914
41 https://molecule.to/
42 "Substandard or Falsified Medical Products", WHO, Retrieved May 16 2022, https://www.who.int/fr/news-room/fact-sheets/detail/substandard-and-falsified-medical-products
43 *Ibid*.

The scientific community has proposed blockchain models and "solutions" to fight drug counterfeiting, including, among others, **LifeCrypter**[44] in 2017, **Drugledger**[45] in 2018 or **PharmaCrypt**[46] in 2020.

All present a distributed ledger as the most appropriate answer to the problems of counterfeit drugs and their traceability, from the production site to the patient:

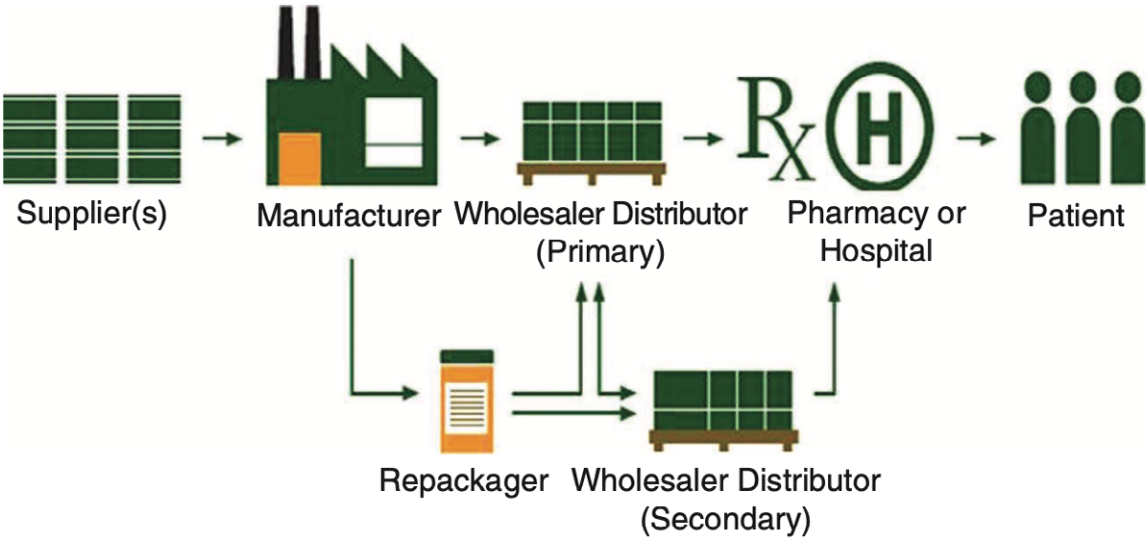
These initiatives start from the observation that a centralized authority is a "single point of failure", and propose the development of distributed registries with smart contracts* to guarantee the transparency of these complex supply chains, among them **StaTwig** founded in Hyderabad, India in 2016, **Meditect**, created in Bordeaux, France in 2017, **Mediledger** created in San Francisco in 2017 or **PharmaTrace**, created in Munich, Germany in 2017.

But many of these initiatives consist of developing private blockchains with permissions, which leads one to believe that the system put in place essentially optimizes the exchange of information between stakeholders without truly guaranteeing true decentralization, immutability of data and transparent control of their access and use, as supported by public blockchains.

Meditect has developed a solution for the traceability and authenticity of medicines sent from Europe to Africa based on the European "Falsified Medicines" directive in force since February 2019. Initiated in 2011, the European directive requires pharmaceutical companies to mark each box of medicine with a unique two-dimensional barcode, a Datamatrix, corresponding in detail to: 1. a unique serial number, 2. the manufacturer's product code in the form of a Global Trade Item Number or GTIN (GS1), 3. a batch number and 4. the expiry date of the medicine, as well as an anti-tampering device on the packaging of medicines subject to prescription.[47]

Meditect has tested, with the pharmaceutical company UPSA, the extension of the European serialization of medicines to those destined for the African market. The company has also developed two mobile applications for pharmacists and patients/clients in Africa. Using *Meditect Pro*, the network pharmacist scans the Datamatrix on the drug box to verify its authenticity.

44 "Blockchain technology in the pharmaceutical industry.", Schöner, M. M., Kourouklis, D., Sandner, P., Gonzalez, E., & Förster, J., 2017, Frankfurt, Germany: Frankfurt School Blockchain Center.
45 "Drugledger: A Practical Blockchain System for Drug Traceability and Regulation.", Huang, Yan & Wu, Jing & Long, Chengnian., Cybermatics, IEEE Explore, 2018, 10.1109/Cybermatics_2018.2018.00206.
46 "PharmaCrypt: Blockchain for Critical Pharmaceutical Industry to Counterfeit Drugs", N. Saxena, I. Thomas, P. Gope, P. Burnap and N. Kumar, in *Computer*, vol. 53, no. 7, July 2020, pp. 29-44, doi: 10.1109/MC.2020.2989238
47 "Falsified medicines: new rules for better patient safety", European Commission, February 8, 2019, https://ec.europa.eu/commission/presscorner/detail/fr/IP_19_872



The pharmaceutical supply chain.
Source : " PharmaCrypt: Blockchain for Critical Pharmaceutical Industry to Counterfeit Drugs, ", N. Saxena, I. Thomas, P. Gope, P. Burnap and N. Kumar, in *Computer*, vol. 53, no. 7, July 2020, pp. 29-44, doi: 10.1109/MC.2020.2989238

The *Meditect Patient* application allows anyone with a smartphone or feature phone* to check that medicines are not falsified. Meditect's client, the pharmaceutical company, can track the distribution and geolocation of its drug sales on an online dashboard.

The system has been tested on Efferalgan boxes sold in Côte d'Ivoire, i.e. about one million boxes,[48] and should soon be deployed in Cameroon and Senegal. From a technical point of view, Meditect's blockchain is a fork* of the Bitcoin Core protocol, adapted to the serialized number exchange and verification service that allows only the laboratory that produced the drug and Meditect to add data to the identifier and allows each stakeholder throughout the life cycle (laboratory, wholesaler, distributor, consumer) to access and verify information on the blockchain using an application.[49] It is a private blockchain with permissions whose source code is public.[50]

In the United States, the **Mediledger** project is presented as a private blockchain with permissions and brings together some 30 supply chain *stakeholders*. The initiative aims to use a distributed registry to comply with the serialization and interoperability requirements of the Drug Supply Chain

48 "How Meditect fine-tuned its drug traceability solution with UPSA", Aurélie Dureuil, MindHealth, March 16, 2021, https://www.mindhealth.fr/industrie/post-commercialisation/comment-meditect-a-peaufine-sa-solution-de-tracabilite-du-medicament-avec-upsa/
49 "Meditect: Saving lives with the blockchain", Cristoffer Harlos, Medium, Oct 17 2018, https://medium.datadriveninvestor.com/meditect-saving-lives-with-the-blockchain-3124b364ae4e
50 "Meditect", Github, retrieved May 16 2022, https://github.com/Meditect/blockchain_go /

Security Act (DSCSA), which will become mandatory in the US in November 2023.[51]

StaTwig, a startup founded in Singapore and India in **2016,** is developing VaccineLedger, *"an open source platform designed to provide end-to-end vial-level traceability of vaccines in the global supply chain".* The startup, funded in part by the UNICEF Innovation Fund was also named a "global innovator" at the World Economic Forum (WEF) in 2020.[52]

The information recorded on the platform includes not only the identification of vaccines on the production line, but also other critical information such as temperature and humidity to ensure that the chain of custody is respected and that vaccines are properly stored. VaccineLedger, whose source code is public[53] under an MIT license, was developed with the help of LACChain,[54] an alliance of different participants in the blockchain ecosystem in Latin America and the Caribbean, led by the Inter-American Development Bank Group's Innovation Lab (IDB Lab).[55]

51 "What You Need to Know about the Drug Supply Chain Security Act", Rob Besse, Pharmexec, Mar 18 2020, https://www.pharmexec.com/view/what-you-need-know-about-drug-supply-chain-security-act
52 "UNICEF Innovation Fund Graduate: Statwig", Sid Chakravarthy, Mar 30 2020, https://www.unicef.org/innovation/fundgraduate/StaTwig
53 "The Ledger", GitHub, retrieved May 16 2022, https://github.com/statwig-com/theledger
54 "Caracteristicas de LACChain", LACCHain, retrieved May 16 2022, https://www.lacchain.net/home?lang=en
55 "About" BID Lab, https://bidlab.org/en/about

ISSUES AND QUESTIONS

As scandals related to the exposure or leakage of health data continue to grow around the world,[1] blockchains and in particular the notion of decentralized identity (see chapter "Identity and Ownership") provide a new response to the management and security of health data.

Indeed, the apparent contradiction in the issues related to these sensitive data is that of ensuring or even guaranteeing their confidentiality, while promoting their sharing according to the context of use. A person may need to share a health document with an employer without the latter accessing and keeping personal information.

The European Blockchain Services Infrastructure (EBSI) is thus planning to launch a "European Social Security Passport" to implement cross-border verification of the social security coverage of detached workers. This means *"that a competent social security institution in one Member State issues a document in the form of a verifiable certificate and an inspector in another Member State verifies it".*[2]

A person may also wish to share his or her health data for medical research purposes with the guarantee that he or she cannot be traced individually.

Innovation in the fields of medicine and medical research depends intrinsically on the quantity of data made available to researchers. This also raises the question of whether or not personal health data is proprietary, with two different views: the Anglo-Saxon view, for which health data can be traded, and the European and French view, which aims to consider this data as sensitive.

Apart from the field of genetic sequencing, where startups are proposing a technical architecture that solves the apparent contradiction between securing customer data and sharing it for scientific research purposes, it is clear that most of the initiatives we have identified are based on the implementation of private blockchains, whether in the fields of patient data management, drug discovery or clinical trials.

1 List of data breaches Healthcare https://en.wikipedia.org/wiki/List_of_data_breaches
2 Navigating the EBSI Use Cases Social security https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Use+cases

The question of the role of States in the implementation of decentralized identity systems, particularly for use in the context of a global reform of information systems handling health data, remains unanswered.

Moreover, the eventual reappropriation of health data by individuals does not resolve the problem of the commodification of health data. Indeed, a system in which individuals are the owners of their health data would allow them to sell it to the highest bidder. While the idea may seem attractive in theory, it does raise ethical questions. Would citizens living below the poverty line be forced to give access to their health data in order to receive aid from the northern hemisphere? How could blockchain initiatives provide a solution to this problem?

In any case, it remains that the blockages are currently more political than technical and that the health market's financial challenges still largely outweigh the social and ethical challenges of the confidentiality of everyone's health data.

ENVIRONMENT & CLIMATE

ENVIRONMENT & CLIMATE

Number of projects in the directory: 102

Number of active projects: 68

Name of active projects: 1PLANET Marketplace ; Arup water exchange ; Atato ; Avano ; BFlo ; BICOWG ; Brokoli Network ; Carbonable ; Carbonfuture GmbH ; CarbonX ; Carbonyzed.xyz ; Changeblock ; Chooose ; Circularise ; Civic Ledger ; Climate Futures ; ClimateDAO ; Climatetrade ; CO2DAO ; CO2ken ; Coorest ; Cut. eco ; DAO IPCI ; dclimate ; Diatom ; DOVU ; Earthbanc ; ecoriseDAO ; Eden DAO ; Empower ; EthaVerse ; Evergreen Coin ; Excess Materials Exchange ; Farm ; Flow Carbon ; Gainforest ; Green World Campaign;"International Platform for Insetting (IPI)" ; Inuk;klimaDAO ; Moonjelly DAO ; Nori ; Open Earth Foundation ; Open Forest Protocol ; OpenSurface ; Pacifical ; Plastic Bank ; PlastiCoin ; PlataformaVerde ; Porini. Foundation ; Poseidon Foundation ; Proyecto Colmena ; RECDefi ; Regen.network ; Reneum (Sindicatum Blockchain Technologies) ; Solarfullcycle ; Solid World DAO ; Sustainable Bitcoin Standard ; TerraBioDAO ; Toucan Protocol ; TREECYCLE ; Treejer ; UPCO2 ; Veridium Labs ; Verity Tracking ; Wood Tracking Protocol ; Wren ; Zero Carbon Project ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

For some, associating blockchains with the environment is an oxymoron. However, a dual movement seems to be at work: firstly to decarbonize the blockchain sector and secondly to accelerate a certain number of the initiatives aimed at fighting climate change and preserving the environment.

Aware of the environmental and ecological issues they raise, some blockchain actors are working to decarbonize the sector.

This is the stated goal of the Crypto Climate Accord, initiated in 2021 by Energy Web, the Rocky Mountain Institute (RMI) and the fair financial systems promoter Alliance for Innovative Regulation (AIR), since joined by more than 250 market participants. The shared ambition is to decarbonize the global crypto-currency sector by *"prioritizing climate stewardship and supporting the transition of the entire crypto sector to net zero greenhouse gas emissions by 2040".*[1]

1 Crypto Climate Accord: https://cryptoclimate.org/accord, Retrieved May 31, 2022.

There are two intermediate goals: first, to "*achieve net zero electricity emissions for Crypto Climate Accord signatories by 2030*"[2] and second, to "*develop standards, tools, and technologies with Crypto Climate Accord members to accelerate adoption and verification of progress towards 100% renewable energy powered blockchains before the United Nations Framework Convention on Climate Change COP30 conference in 2025*".[3]

Preceding this recent initiative, it is important to note that the issue of climate and the environment has been driving the crypto community, and beyond, for several years. The Blockchain & Climate Institute (BCI), based in London since 2016, is a think tank and action group that aims to facilitate the implementation of the Paris Agreement. Similarly, the Climate Chain Coalition is an organization with the status of official observatory of the United Nations Framework Convention on Climate Change (UNFCCC).

Created in Paris in December 2017, headquartered in Ottawa, Canada, and 170 members strong across 44 countries, it aims to mobilize climate finance and improve the so-called Measurement, Reporting and Verification (MRV) mechanisms in order to intensify the fight against climate change.

Another observable trend is the multiplication of blockchain projects dedicated to fighting climate change and preserving the environment.

The variety of projects in this field is worth highlighting: decentralization of voluntary carbon markets, water markets, financing of waste collection, crypto-currency donations earmarked for environmental projects, or even agroecology and reforestation projects.

The topics of decentralization of energy exchanges, energy certificates (savings, renewable sourcing guarantees, ...) and grid optimization, are addressed in the chapter entitled "Energy".

The chapter "Peer-to-Peer Electronic Cash System and Programmable Money" also deals with finance dedicated to the development of renewable energies.

2 *Ibid.*
3 *Ibid.*

Climate and Carbon Reduction

The carbon market has been one of the cornerstones of Europe's energy and climate policy since 2005, when the European Union Emissions Trading System (EU ETS)[4] was launched. Since then, the number of emissions trading markets around the world has grown steadily, particularly in the United States since 2009, but also in Canada, Australia, China, Japan, New Zealand, South Korea, Switzerland, and China, to name just a few.

On July 14, 2021, the European Commission adopted a series of legislative proposals outlining how it intends to achieve climate neutrality in the European Union by 2050.

Today, the EU Emissions Trading Scheme applies to 11,000 European installations, which are responsible for about 50% of CO2 emissions and 40% of overall greenhouse gas emissions in the European Union.[5]

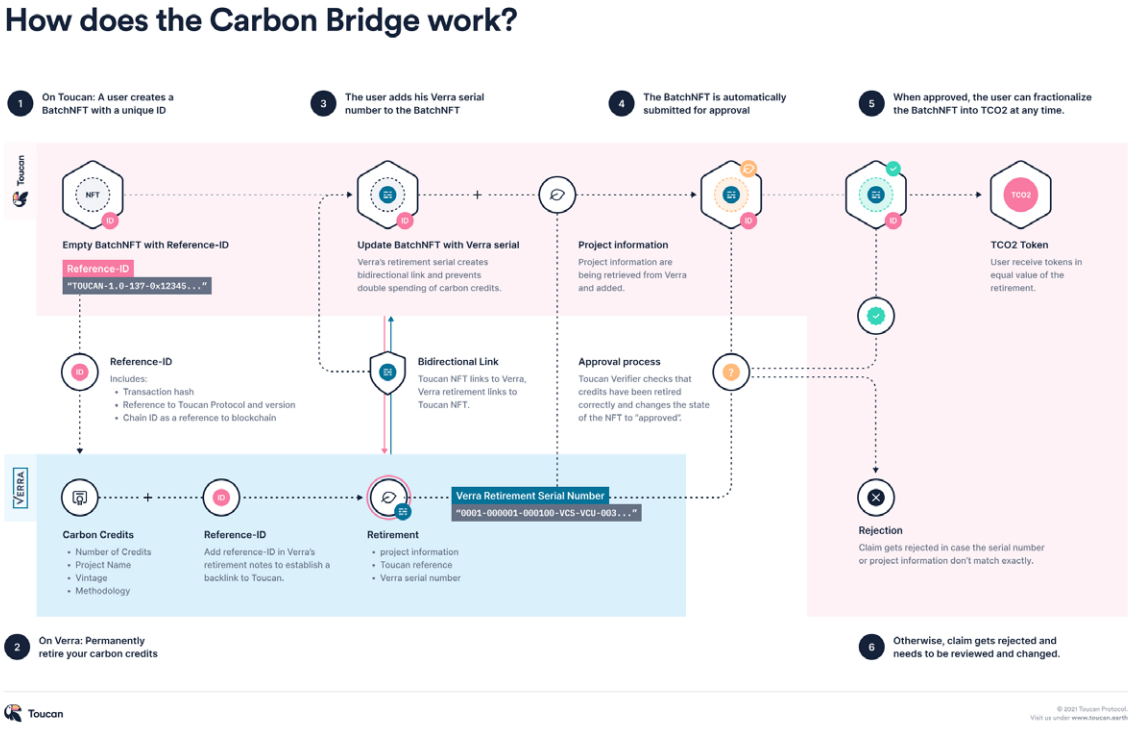
This carbon market is designed to trade carbon credits, with the objective of providing economic incentives to reduce emissions.

Each credit unit represents the reduction or removal of one tonne of CO2 equivalent from the atmosphere. This also includes the carbon sequestered or avoided through project implementation.

There are two types of markets: 1. those that are mandatory ("compliance" markets), in which participants are subject to country-wide and industry-wide emissions limits, and 2. those that are voluntary, not regulated by a government authority, but governed by administrators of carbon emission reduction certification standards, such as the Verified Carbon Standard (Vera),[6] the American Carbon Registry,[7] or the Gold Standard.[8]

In voluntary carbon markets, there is no limit to the number of carbon credits generated by positive-impact climate projects that others can purchase to offset their emissions. It is into these markets that blockchains have invited themselves: *"many Web3 projects are innovating in the carbon value chain, as blockchains intrinsically improve the transparency, traceability, programmability and tradability of carbon offsets, explains Louise Borreani of Curve Labs*.[9]

4 "EU Emissions Trading System (EU ETS)"; European Commission, retrieved May 16 2022, https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en
5 "Marchés du carbone > Le système européen d'échanges de quotas d'émissions de gaz à effet de serre (SEQE)", Ministère de la transition énergétique, December 21, 2021, https://www.ecologie.gouv.fr/marches-du-carbone
6 Vera: https://verra.org/project/vcs-program/
7 American Carbon Registry: https://americancarbonregistry.org/
8 Gold Standard: https://www.goldstandard.org/
9 "Cybernetic solutions for the distributed economy", Curve Labs, retrieved May 16 2022, https://blog.curvelabs.eu



" How does Carbon Bridge Work ", Toucan Protocol.
Source : Toucan Protocol, May 16 2022, https://docs.toucan.earth/protocol/bridge/carbon-bridge

Toucan Protocol, **Nori**, the **Cambridge Centre for Carbon Credits**, **Moss**, **Klima DAO**, **Climate Trade**, **Wren** and **CO2 DAO** are just some of the projects that are adding fluidity to traditional voluntary carbon markets, of which there will be around 20 by 2020 according to the report published by the International Carbon Action Partnership Status Report.[10]

Toucan Protocol, created in 2020, defines itself as *"a market infrastructure to bring carbon markets to public blockchains"*. The protocol allows anyone to tokenize* their carbon credits, registered on the Vera registry, and make them available in the emerging world of decentralized finance (DeFi*),[11] as illustrated by the partnership between Toucan Protocol and **Celo** (see below).

The protocol, which is open source,[12] implements a "Carbon Bridge" and the Base Carbon Tonne (BCT) token, in other words a gateway for carbon credits (Verified Carbon Units / VCUs) from the Vera[13] registry to the Toucan Protocol

10 "Emissions Trading Worldwide: Status Report 2020. Berlin: International Carbon Action Partnership", ICAP, 2020, https://icapcarbonaction.com/system/files/document/200323_icap_report_web.pdf
11See Chapter "Peer-to-peer Electronic Cash System and programmable money".
12 "Smart contracts of the Toucan Protocol", Github, retrieved May 16 2022. https://github.com/ToucanProtocol/contracts
13 "Verified Carbon Units (VCUs)", Verified Carbon Standard, retrieved May 16, 2022. https://verra.org/project/vcs-program/verified-carbon-units-vcus/

public blockchain (the BCT token). Built on the Polygon[14] blockchain, the Toucan Protocol deploys a set of smart contracts*[15] that guarantee the origin of carbon credits and also ensure greater liquidity by pooling them in carbon pools.

These new financial instruments are made available in all applications of decentralized finance built around the Ethereum ecosystem. The consensus mechanism of the public blockchain is based on proof of stake*, and is also compatible with other applications such as **Klima DAO**, which we will discuss later.

As of May 2022, 18.3 million tons of carbon credits from the Vera registry, corresponding to 167 climate projects, have been tokenized on the Toucan Protocol[16] blockchain and available to the Decentralized Finance ecosystem.

Celo,[17] a permissionless public blockchain which specifically targets populations that are excluded from the traditional banking system and allows anyone with a smartphone to send and receive crypto-currencies and stablecoins (dollars, euros and Real) partnered with Toucan Protocol in April 2022.

Toucan and Celo plan to create a Celo-Polygon bridge in collaboration with Curve Labs to allow users to transfer their Base Carbon Tonne (BCT) and Nature Carbon Tonne (NCT) tokens, between Celo and Polygon.

Once this bridge is created, Toucan will be launched on the Celo blockchain and will allow anyone in the ecosystem to *"access, deposit into pools and withdraw TCO2 (tokenized carbon credits) and trade BCT and NCT for carbon tokens held in pools"*.[18] Celo also plans to launch a *"grant program in the future to increase the number of ReFi*[19] *projects in the Celo ecosystem"*.[20]

Founded in 2017, **Nori** bills itself in its 2019 white paper[21] as *"a blockchain-based marketplace for removing carbon dioxide from the atmosphere"* based on *"regenerative agriculture"*.

14 Polygon is a layer two or sidechain scaling solution that works alongside the Ethereum blockchain, enabling fast transactions and low fees.
15 Words marked with an asterisk refer to the glossary.
16 "Carbon On-Chained", Toucan Protocol, retrieved May 16 2022, https://toucan.earth/
17 See Chapter "Peer-to-peer cash systems and programmable money" et https://celo.org/
18 "The Celo Foundation, Climate Collective, and Toucan Collaboration Deepens to Bring ReFi to the Masses" Celo Foundation, Apr 11 2022.
19 Regenerative finance; see in particular "The Promises and Pitfalls of Regenerative Finance Towards a Critical Yet Constructive Dialogue", Curve Labs Curve Labs, May 23 2022. https://blog.curvelabs.eu/the-promises-and-pitfalls-of-regenerative-finance-4910f0f6f690
20 *Ibid.*
21 "A blockchain-based marketplace for removing carbon dioxide from the atmosphere. Version 3.0.1", NORI, Feb 18 2019, https://storage.googleapis.com/nori-prod-cms-uploads/white_paper_e567a48109/white_paper_e567a48109.pdf

Regenerative Agriculture

Source: Novethic, accessed on May 16, 2022, https://www.novethic.fr/lexique/detail/agriculture-regeneratrice.html

Regenerative agriculture is a set of farming methods - inspired by traditional peasantry and permaculture - that aim to regenerate degraded soils, increase biodiversity and fight climate change by promoting carbon dioxide retention.

In this way, regenerative agriculture helps to reduce CO2 levels caused by the use of mineral fertilizers and agrochemicals. Regenerative agriculture relies mainly on the elimination of ploughing, which destroys the soil; the establishment of cover and intercropping crops, crop rotation and the application of compost to increase soil fertility biologically; the maintenance of biodiversity and the regeneration of soils through the restoration of bacterial flora; and the use of grazing. Regenerative agriculture combines productivity and protection of ecosystems in the long term.

Nori has implemented a Carbon Removal Certificate (CRC) from smart contracts* based on the Ethereum blockchain, representing a token corresponding to one ton of CO2 removed. This Carbon Removal Certificate is created from a modified version of the non-fungible token standard ERC-721, in combination with the advanced token standard ERC-777 which gives it non-fungible properties, making it possible to both distinguish each certificate and make them divisible to gain liquidity.[22]

The Nori marketplace connects: 1. farmers who commit to regenerative practices by providing historical data on their projects, 2. Third-party verifiers who then *"legitimize this data by ensuring that it is reasonable, legally permitted and are not included in other registries. Second, a third-party quantification tool creates carbon removal estimates that inform Nori's NRT token generation. Finally, 3. buyers can purchase Nori carbon removal tons (NRT) from suppliers".*[23] As a result, Nori has sold more than 78,000 tons of CO2 removal and paid some $1.3 million to farmers who have implemented such practices.

The open and decentralized nature of permissionless public blockchains allows anyone to deploy other initiatives that build on their decentralized architecture, such as, for example, KlimaDAO.

22 "A blockchain-based marketplace for removing carbon dioxide from the atmosphere. Version 3.0.1", NORI, Feb 18 2019, https://storage.googleapis.com/nori-prod-cms-uploads/white_paper_e567a48109/white_paper_e567a48109.pdf
23 "Our Mission is to reverse Climate Change", NORI, retrieved May 16 2022, https://nori.com/litepaper

KlimaDAO, not to be confused with ClimateDAO, is a Decentralized Autonomous Organization* (DAO) and a Decentralized Finance Protocol (DeFi) implementing a token called KLIMA. This establishes a decentralized and open carbon market, conceptualized and built by a distributed and pseudo-anonymous team,[24] inspired by OlympusDAO (another DeFi protocol that has already attracted more than $500 million since its implementation in May 2021, hosted on the Ethereum blockchain, and which aims to create a monetary reserve backed by a basket of crypto-currencies).

KlimaDAO's goal is *"to encourage emissions reduction by driving up the price of carbon assets".*[25] *This* process can be compared to "activist investors", investors who buy shares in order to gain influence and put pressure on the management of a company so that it directs its strategy according to their demands. The Lazard bank, which conducts an annual survey of these funds, estimated that in 2021 funds would have $42 billion "in minority stakes in the capital of listed companies that are supposedly poorly managed, with the aim of influencing their strategy*".*[26]

According to the KlimaDAO team, *"the more costly the negative externality of damage becomes, the more profitable the decision to reduce emissions and invest in green solutions"*. In other words, KlimaDAO's mechanism involves taking credits out of the voluntary carbon market and placing them in the DAO's treasury, with the effect of increasing the cost of carbon offsets and making them more expensive for carbon-intensive companies.

KlimaDAO, which is open source,[27] implements an ERC20 token according to the Ethereum standard, called KLIMA, indexed to the BCT (Base Carbon Tonne) token corresponding to a credit - equivalent to one ton of carbon - issued on the Toucan Protocol blockchain (see above), coming from Vera's Verified Carbon Units (VCUs). These KLIMA tokens can be traded on the decentralized exchange platform* (DEX) Sushiswap. They are blocked in the Klima DAO treasury and their holders vote on the policy of the Decentralized Autonomous Organization*. KlimaDAO thus acts, in their words, as a *"de-central bank by governing the monetary policy of this new carbon-backed currency, just as a central bank governs the monetary policy of a*

24 Pseudo-anonymity allows someone to post and comment anonymously, without an identifier being visible, with the information about them being in the possession of the service provider or website administrator.
25 What is Klima DAO and How Does it Work? https://www.coingecko.com/buzz/what-is-klima-dao-and-how-does-it-work
26 "Les Fonds activistes ont davantage choisi leurs cibles", Guillaume Bayre, TradingSat, 6 février 2022, https://www.tradingsat.com/actualites/marches/en-2021-les-fonds-activistes-ont-davantage-choisi-leurs-cibles-1004759.html
27 "KlimaDAO", Github, retrieved May 16 2022, https://github.com/KlimaDAO/klimadao

fiat currency".[28] The DAO has acquired more than $120 million in carbon offsets via Toucan Protocol in a short period of time.

According to McKinsey, the price of a ton of carbon is expected to rise in the coming years, so that *"demand for carbon credits could increase by a factor of 15 or more by 2030 and by a factor of up to 100 by 2050"*,[29] for a market estimated at $50 billion in 2030. Klima DAO is betting that it will soon be more profitable for companies generating too many emissions to change their practices than to rely on buying carbon credits.

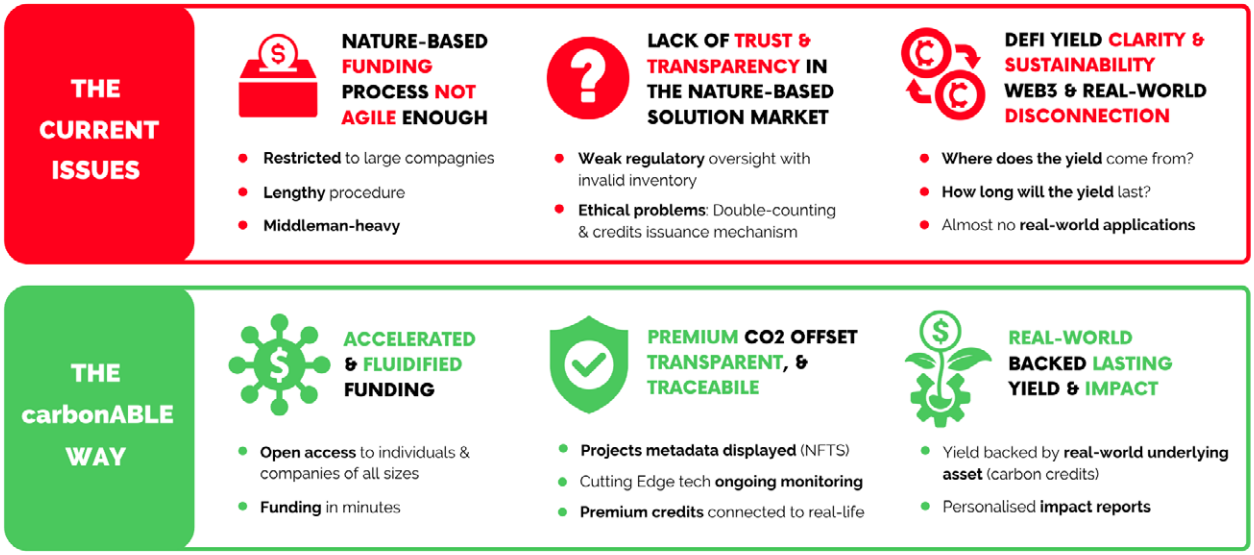
While all of these initiatives address the financial dimension of carbon markets, others aim to **make voluntary carbon markets accessible to as many people as possible** while allowing companies to **verify the impact of projects financed by credits**, an aspect that is regularly criticized. This is the ambition of **CarbonABLE**, created in Grenoble, France in November 2021, and of the **Cambridge Centre for Carbon Credits (4C)**, created at the University of Cambridge in England, at the same time.

CarbonABLE combines NFTs* and decentralized finance to finance "carbon sinks", environmental projects capable of capturing and sequestering carbon. CarbonABLE is built on the Cosmos (Atom) blockchain, notably because it uses a consensus mechanism based on proof of stake*, which requires little energy.

Decarbonization projects[30] are proposed on the CarbonABLE platform and funded in the form of NFT* sales, due to their non-fungible nature. Once financed, CarbonABLE receives the first carbon credits corresponding to the project after 6 months. NFT* holders then get a financial return in stablecoins and in CARBZ, a token of governance and yield enhancement.

Projects funded through CarbonABLE are tracked in real time by Wild Sense,[31] which was created with the support of the European Space Agency to select, certify, monitor and guarantee carbon credit projects.

28 "Enter : KlimaDAO", KlimaDAO, retrieved May 16 2022, https://docs.klimadao.finance/#8b79
29 "A blueprint for scaling voluntary carbon markets to meet the climate challenge", Christopher Blaufelder, Cindy Levy, Peter Mannion, and Dickon Pinner, McKinsey, Jan 29 2021, https://www.mckinsey.com/business-functions/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge
30 Décarbonation : *ensemble des mesures et des techniques permettant de réduire les émissions de dioxyde de carbone*. Vocabulaire de l'environnement : climat-carbone, Journal Officiel de la République française, 24 septembre 2019. https://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/joe_20190924_0222_0049.pdf
31 Wild Sense: https://www.wildsense.co/



CarbonABLE Lite Paper, Source, CarbonABLE : https://carbonable.notion.site/carbonable/CarbonABLE-Lite-Paper-82bda161f3594964931b2be7d84429ff#7cb3ab5a31fc492e8333c2d2efb786ec

A first sale of NFTs* in May 2022 that aims to plant *"8,000 native species on four hectares in order to connect different parts of the Golfo Dulce reserve in southern Costa Rica"*[32] has been successfully launched.[33]

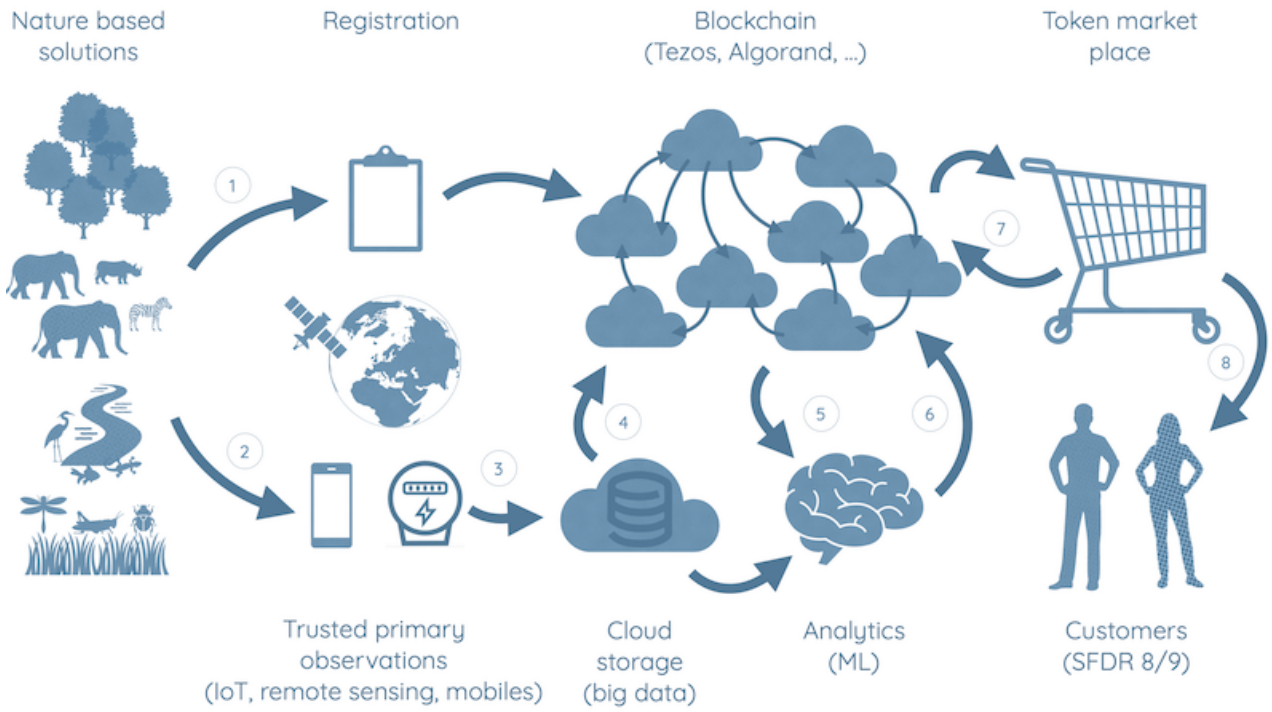
A dozen decarbonization projects spread over four continents are in the financing phase, representing nearly one million tons of CO2 credits.

CarbonABLE is in this way addressing several criticisms made against carbon markets.

The Cambridge Centre for Carbon Credits (4C) aims to create *"a trusted, decentralized marketplace where buyers of carbon credits can directly and confidently finance nature-friendly projects".*[34]

This platform, currently under development, will rely on the Tezos public blockchain to connect companies that finance carbon offset projects with environmental project owners, notably through decentralized*, automated and transparent oracles, based on satellite imagery.

32 Wild Sense, Costa Rica Banegas: https://www.wildsense.co/projects
33 "CarbonABLE's First Mint: 160 NFTs restoring the forest at Banegas Farm!", CarbonABLE, May 3, 2022. https://carbonable.medium.com/banegas-farm-reforesting-to-be-finance-by-carbonables-160-nfts-b4b36b5a4645
34 "Learn about our approach and first prototype", Cambridge Center for Carbon Credit, retrieved May 16



How the decentralised marketplace for nature-based solutions works
Source : Cambridge Centre for Carbon Credit,
retrieved May 16, 2022, https://4c.cst.cam.ac.uk/about/marketplace

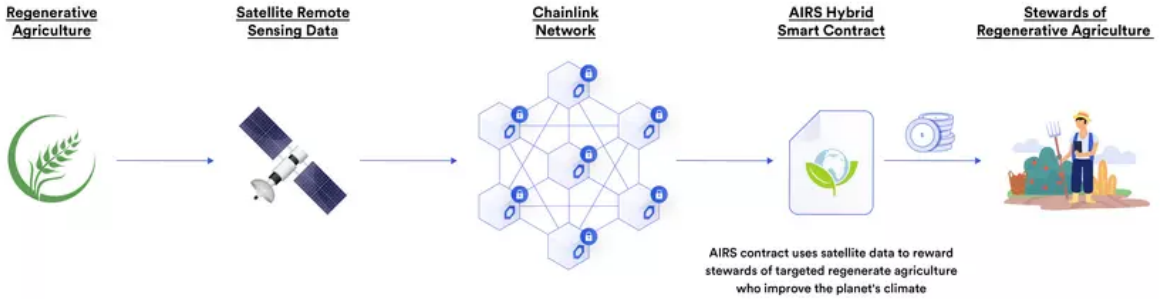
According to the Cambridge Centre for Carbon Credits, *"the algorithmic system is capable of not only retrospectively quantifying the positive externalities that arise from project areas, but also predicting their potential"*, one of the weaknesses of conventional standards for certifying carbon emissions reductions.

Alongside a carbon offset offer aimed at companies, individuals are also being offered the opportunity to offset their greenhouse gas emissions by a number of blockchain projects such as **Dovu**, created in 2016 in Wales, England, **Chooose**, created in 2017 in Oslo, Norway, or in the United States, **Climate Futures** in 2018 and **Flow Carbon** in 2021.

These services, sometimes confusing as to how they proceed, promise to allow an individual to calculate and offset their carbon footprint through the choice of a project to finance. These carbon credits, tokenized, often come from traditional registries such as Vera or Gold Standard.

Another way to fight against global warming is through reforestation projects such as those led by **Open Forest Protocol**, **GainForest** or the program jointly led by **Green World Campaign** and **Cornell University** with the support of the decentralized oracle **ChainLink**.

2022, https://4c.cst.cam.ac.uk/



ChainLink Labs Blockchain can help us beat climate change. Here's how.
Source : Adelyn Zhou, WeForum, Jun 30 2021,
https://www.weforum.org/agenda/2021/06/blockchain-can-help-us-beat-climate-change-heres-how/

Founded in 2020 in Geneva, **Open Forest Protocol** aims to "*transparently measure, verify and finance agroforestry projects using blockchain technology*". Twenty-seven reforestation projects are currently underway in Kenya, Costa Rica, Panama, Colombia and South Korea. The most recent, initiated in 2022 with Ivory Coast, involves local communities and a non-governmental organization to reforest and restore more than 5,000 hectares of degraded forest land in the Gorké region.[35]

Open Forest Protocol is a decentralized application (dApp*) built on the NEAR protocol,[36] a blockchain protocol that allows the development of smart contracts*, interoperable with the Ethereum blockchain.

The consensus mechanism of the NEAR protocol is based on delegated proof of stake*, which uses sharding, i.e. the partitioning of a database in order to reduce the risk of network centralization and to offer faster and less expensive transactions.

To account for the geospatial nature of reforestation, the decentralized application generates non-fungible tokens (NFTs*) that represent an area within which a reforestation project is underway.

35 "Open Forest Protocol tackles climate change naturally", Julie Mollins, ForestNews, Apr 18 2022, https://forestsnews.cifor.org/76905/blockchain-platform-offers-reforestation-efforts-access-to-carbon-finance
36 Launched in 2020 by Illia Polosukhin and Alexander Skidanov, Near Protocol enables the development of decentralized applications (Dapps), which relies on proof of stake smart contracts. Near Protocol has raised $533 million since its launch (Source: Crunchbase.com)

The reforestation project information is stored on IPFS,[37] a distributed system for storing and accessing distributed content, and the NFTs'* metadata are updated *"so that all reforestation project information is fully transparent and traceable throughout the life of the project"* and could eventually permit the emission of carbon credits.

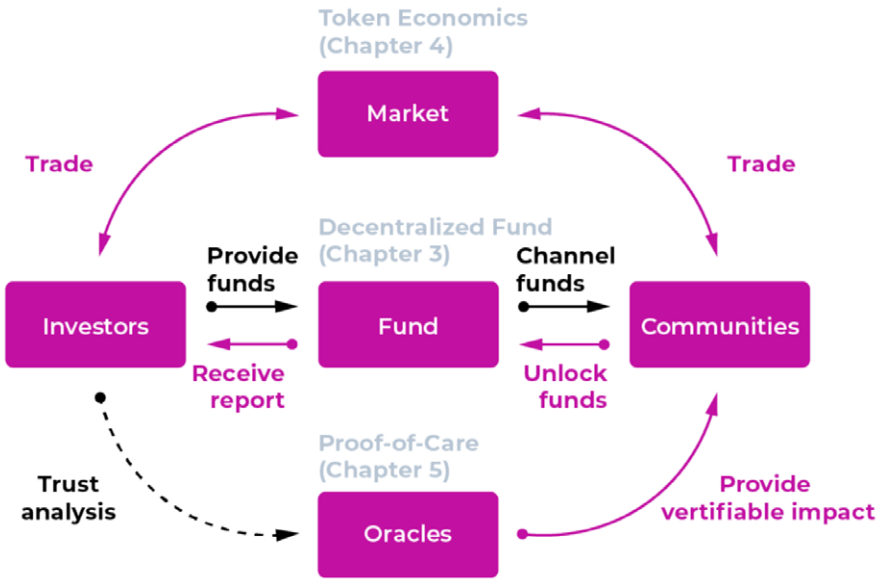
Most reforestation projects aim to link local communities with validating organizations, as well as financial partners and entrepreneurs within a single decentralized community. But Open Forest Protocol also implements Measurement, Reporting and Verification (MRV) tools including satellite imagery, artificial intelligence and Internet of Things (IoT) sensors to certify or not the progress of projects.
Another reforestation initiative is led by **Green World Campaign**, an American association, in partnership with **Cornell University** with the support of the decentralized oracle* **ChainLink**.

Since 2012, **Green World Campaign** has been engaged in Kenya, India, Ethiopia, and Mexico on agroecology projects, combining reforestation of trees and other plantings. In Kenya, **Green World Campaign** has already planted *"3.75 million trees, established 100 eco-school programs, and provided farmer training, women's and children's health and rural livelihoods".*[38]

In 2021, smart contracts* have been developed to automatically reward people for regenerating plots of land by increasing vegetation cover, improving soil, and implementing other restorative agricultural practices, identified via satellite data.

"When Chainlink's oracles provide proof of a land's improvement (via satellite imagery) on the blockchain, the smart contract triggers a cash payout. With this system, land stewards can receive their rewards quickly and efficiently.*

37 IPFS or InterPlanetary File System is a peer-to-peer (P2P) protocol for hypermedia addressable content distribution. It allows to "store" files or file trees in a decentralized and permanent way, and to access them via an ipfs node or via a web browser. It can also be used to host a statistical web site. See Chapter "Web 3.0, Arts & Sciences".
38 "We all have the power to regreen the world" Greenworld, retrieved May 16 2022, http://greenworld.org/



Vue d'ensemble de tous les acteurs et modules impliqués dans la plateforme Gain-Forest. Les transactions permettent de lever des fonds (en noir) ou sont des incitations basées sur des tokens (en violet). *Source :* " GainForest White Paper.Version 1.5.0 ", GainForest Non-Profit, retrieved May 16 2022, https://drive.google.com/file/d/1k7V8g2eHDgDSw_kttObaOy5IrksnuHal/view

At the same time, only those who make a real impact can get rewards, as payment only occurs when a real-world condition is met and verified on the blockchain. The entire process is automated, scalable and fraud-proof, and can be replicated in hundreds of use cases across industries",[39] explains Adelyn Zhou of Chainlink Labs.

As for **GainForest**, which won the Hack4Climate competition at UN COP 23 in 2017 and was officially established two years later in Zurich, the project bills itself as *"a decentralized fund using artificial intelligence to measure and reward sustainable nature management".*[40] It is built on the **Solana** blockchain, due to its low carbon footprint.

Overview of all stakeholders and modules involved in the Gain-Forest platform. Transactions either raise funds (black) or are token-based incentives (purple).

The project collects donations in crypto-currencies to *"buy forests from landowners, expand national parks and prevent deforestation".*[41] The price of one hectare of virgin rainforest in Paraguay, for example, is $300.

39 "How will blockchain technology help fight climate change? Experts answer.", Max Yakubowski, CoinTelegraph, Sep 05 2021 https://cointelegraph.com/explained/how-will-blockchain-technology-help-fight-climate-change-experts-answer
40 "A crypto-currency to reverse deforestation", GainForest, retrieved May 16 2022, https://www.gainforest.net/
41 *Ibid.*

Donors receive information and photos about the project they have funded in the form of non-fungible tokens (NFTs) that Gain Forest calls NFTrees. The project combines smart contracts* built on **Solana**.

The Measurement, Reporting and Verification (MRV) system relies on satellite images coupled with drone photography and data processing based on artificial intelligence algorithms. Since the beginning of 2022, GainForest has been working with the Paraguayan Ministry of the Environment to protect several thousand hectares of rainforest in Paraguay's Gran Chaco Americano.

This is one of the most vulnerable areas to climate change, and one of the planet's main carbon sinks.[42] It extends partly over the territories of Argentina, Bolivia, Brazil and Paraguay, between the Paraguay and Paraná rivers in the east, and the Andean Altiplano in the west.

Pollution and Waste

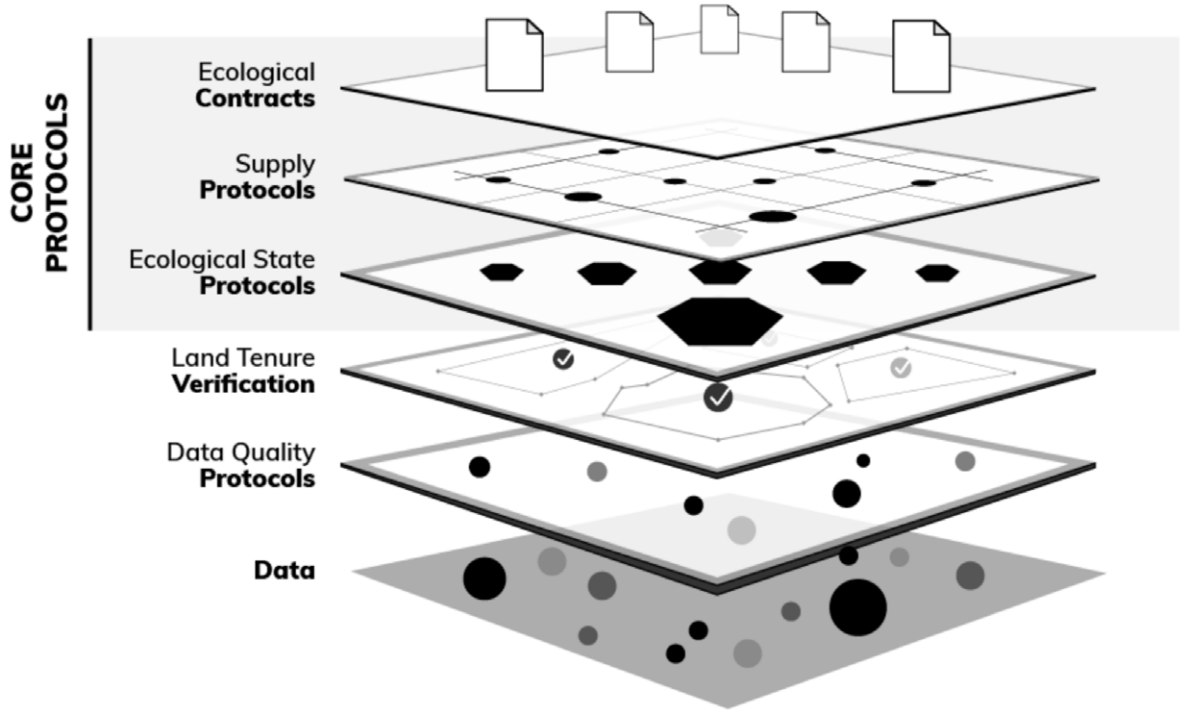
Regen Ledger, established in 2017 in the US state of Delaware, is a public proof-of-stake* (PoS) blockchain developed with the **Cosmos** SDK* and designed *"for verification of claims, agreements, and ecological status data".*[43]

Regen Network provides an open platform designed specifically to run a variety of applications *"such as regenerative carbon credits,*[44] *supply chain transparency, reforestation tracking and investment vehicles such as green bonds".*[45]

Regen Network's white paper, updated on February 15, 2021,[46] proposes *"the creation of a decentralized system to monitor and verify the ecological status and change in status [of places], (...) to create an ecological ledger that can reward ecological regeneration through smart contracts"*.

Regen Network's proposal is to *"reward ecological regeneration"* through smart contracts*.[47]

42 "Solana-Based Climate Change Project Employs 'NFTrees' to Save Rainforests", Ian Allison, Coindesk, Apr 21 2022 https://www.coindesk.com/business/2022/04/21/solana-based-climate-change-project-employs-nftrees-to-save-rainforests/
43 "Our Approach", Regen Network, retrieved May 16 2022, https://www.regen.network/developers/
44 Working with the American Carbon Registry, Verra and Gold Standard.
45 "Regen Network Development, Inc", LinkedIn, retrieved May 16 2022, https://www.linkedin.com/company/regen-network/about/
46 "Regen Network Whitepaper. Version 1.3", G. Booman, A. Craelius, B. Deriemaeker, G. Landua, W. Szal, B. Weinberg, Regen Network, Feb 15 2021, https://regen-network.gitlab.io/whitepaper/WhitePaper.pdf
47 "Regen Network Economics Technical Paper An Ecological Market-Commons, Secured by Proof-of-Stake. Version 0.2", G. Landua, K. Birchard, W. Szal, Regen Network, Feb 16 2021, https://regen-network.gitlab.io/whitepaper/Economics.pdf



How Regen is Creating an Eco-Friendly Blockchain
Source : Regen Network, November 5, 2018, retrieved May 16 2022, https://medium.com/regen-network/lets-cut-to-the-chase-for-all-the-great-environmental-projects-blockchain-supports-it-s-a-c3ea96401c28

The Regen Ledger blockchain architecture brings together three concepts to connect the ecological state of a place with participatory funding:

- Ecological State Protocols (ESPs), which define, via algorithms, the conditions necessary to verify the change of state on a parcel.
- Supply Protocols (SPs), which reliably link ecological state to supply chains.
- Ecological Contracts (ECs) that allow for financing and remuneration following state change.

Several soil carbon sequestration projects built on the Regen Network are currently underway in Australia, the United States, the Democratic Republic of Congo, Kenya, and Ecuador.[48]

Eco-Cacao, a cooperative of farmers producing cocoa in the province of Esmeraldas, Ecuador, manages agroforestry farms in the Chocó-Darién region, which stretches along the Colombian Pacific coast from southwestern Panama to northeastern Ecuador.

48 "Discover Ecocredits and NCT Basket tokens", Regen Registry, retrieved May 16 2022, https://registry.reg

Eco-Cacao verifies sustainable land management and pays a premium to farmers who successfully manage farms that replicate native forest, thereby generating high carbon sequestration yields while increasing biodiversity on the farm.

The status of the land parcels is recorded on the Regen Ledger blockchain in order to have a transparent view of them and to proceed with the payment and financing of their ecological management. They are currently triggered by two third-party certifiers involved in the project: Terra Genesis International[49] and the Seed Guardian Network.[50]

Regen Network relies on a variety of data sources to verify the ecological status of plots, including remote sensing data such as satellite and drone imagery, data from Internet of Things (IoT) sensors, public Geographic Information Systems (GIS) data, and user-submitted data such as soil test results.

In the field of pollution control, especially plastic in the oceans, **Plastic Bank**, started in 2013 from Canada and **Ocean Plastik** created in 2018 from the Czech Republic, but whose activity seems to be suspended since the Covid 19 epidemic, both rely on a simple concept:

"cleaning the oceans by paying people to collect plastic waste - which also generates income to help them improve their lives".[51]

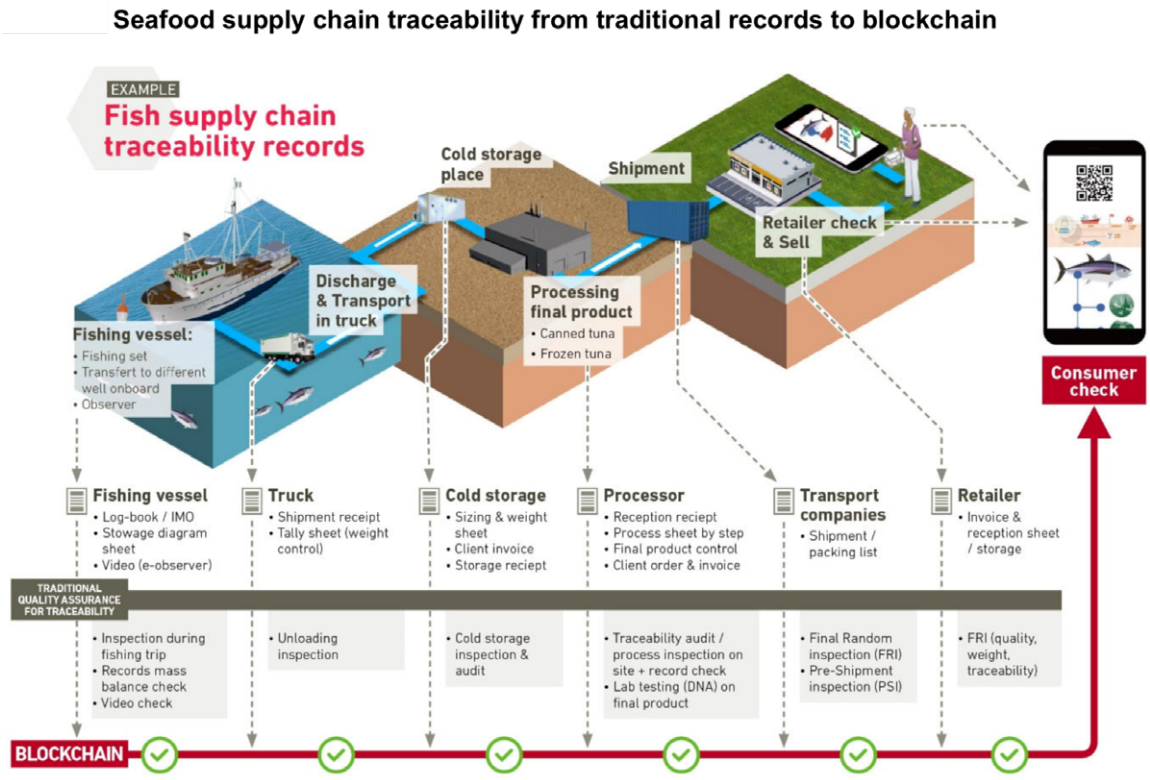
Plastic Bank, whose waste collection activities are currently underway in Brazil, Indonesia, the Philippines and Egypt, creates *"ethical recycling ecosystems in coastal communities and re-processes the materials back into the global supply chain"*.

According to Plastic Bank, the equivalent of 41,000 tons of plastic will have been collected by January 26, 2022. 38,000 people are reportedly registered as collectors on the platform.

Collecting and paying for recovered plastic has allowed them to increase their revenue by 40%. The platform is built by IBM on Hyperledger Fabric, a private and permissioned blockchain, preventing us from having access to their data.

As for Ocean Plastik, they hope to launch RPNDEX[52] sometime in 2022, a decentralized B-to-B marketplace that will provide recycling companies and plastic manufacturers a single platform to buy and sell recycled plastic pellets.

49 Tera Genesis: https://terra-genesis.com/
50 Seed Guardian: https://www.gardenorganic.org.uk/seed-guardians
51 "Plastic Bank", IBM, retrieved May 16 2022, https://www.ibm.com/case-studies/plastic-bank-systems-linuxone
52 "Decentralized Marketplace for recycled plastic materials", RPNDex, retrieved May 16 2022, https://www.rpndex.com/



Food traceability

Source : Bureau Veritas. White Paper (2017) *in* Blaha, F. & Katafono, K. 2020. " Blockchain application in seafood value chains ". FAO Fisheries and Aquaculture Circular No. 1207. Rome, FAO. https://doi.org/10.4060/ca8751en https://www.fao.org/3/ca8751en/ca8751en.pdf

Life below Water

Fisheries and fishery products are, according to the Food and Agriculture Organization of the United Nations (FAO), *"among the most traded foodstuffs in the world, with, in 2016, about 35% of the world's fish production traded internationally".*[53] 60% of that total amount comes from developing countries. How do we ensure that fishing operations do not deplete natural resources? Sustainable Development Goal 14 aims to provide *"a framework for the sustainable management of marine and coastal ecosystems and their protection from the impacts of human activities".*[54]

Several blockchain initiatives fall within the realm of fisheries value chain traceability, including **Provenance** in Indonesia since 2016, **WWF-New Zealand**, **ConsenSys**, **Sea Quest**, **TraSeable Solutions** in Fiji in 2017, **Pacifical**, **Atato Pacific** in 2018, **OpenSC**, **WWF-Australia**, **BCG Digital Ventures Australia** in 2019, **Bumble Bee Foods** in March 2019, **Fishcoin** in 2018, **Sustainable Shrimp Partnership**

53 "Blockchain Application in seafood value chains", Francisco Blaha, Kenneth Katafono, FAO, 2020, https://www.fao.org/3/ca8751en/CA8751EN.pdf
54 Goal 14: Conserve and sustainably use the oceans, seas and marine resourceshttps://www.un.org/sustainabledevelopment/fr/oceans/

in Ecuador in May 2019. All of these experiments provide tuna traceability via a private blockchain, except for **Pacifical which has developed a platform on the Ethereum blockchain**. The promise of these initiatives is summarized by Bureau Veritas through the previous diagram p.151.

The chapter "Agriculture and Food" is dedicated to the traceability of food and fishery products.

Sanitation & Water

Because 2.2 billion people do not have access to safely managed drinking water, and more than 4.2 billion people do not have access to sanitation, Sustainable Development Goal 6 calls for *"universal and equitable access to safe drinking water, hygiene and sanitation by 2030, especially for vulnerable populations. It also calls for sustainable management of this resource, and mentions reducing the number of people suffering from water scarcity. This goal incorporates the notion of transboundary water management, which is essential for sustainable management but also promotes peace and cooperation".*[55]

According to Therese Flapper, Senior Associate - Infrastructure and Water at Arup, a UK-based engineering consultancy, *"blockchains are an ideal technology for tracking water transactions and compliance activities. Regulators, water users and all stakeholders have the same copy of water transaction and compliance information across an entire water system, with no discrepancies".*[56]

Several blockchain initiatives are being tested in the sanitation and water management space, including challenging centralized systems owned and operated by a single entity, whether private or public, or addressing the complexity of water markets that rely on too many intermediaries. Other initiatives are directing cryptocurrency investments toward water projects.

The water market often involves many intermediaries. Hence the idea of setting up smart contracts* to quickly manage the supply, delivery and billing of water, including in a changing context such as drought.

Proponents of these initiatives emphasize transparency of production and transactions for all users of a water system. This fosters stakeholder engagement and accountability, while allowing for the elimination of a certain number of intermediaries, or at least the automation of many particularly time-consuming manual processes.

55 SDG 6 - Ensure access to water and sanitation for all and ensure sustainable management of water resources, https://www.agenda-2030.fr/17-objectifs-de-developpement-durable/article/odd6-garantir-l-acces-de-tous-a-l-eau-et-a-l-assainissement-et-assurer-une

56 "Blockchain and the built environment.Version 1.2", ARUP, Feb2019, https://www.arup.com/

The case of Australia illustrates the problems faced by water trading markets when they are managed in a relatively opaque manner. The most active water trading market in Australia is the Murray-Darling Basin (MDB) market, where 97% of all allocation trading and 77% of all entitlement trading is conducted.[57] During each drought, this market is criticized in particular *"for its lack of information about who is trading what resources and who ultimately benefits from these trades".*[58]

In 2020, **Civic Ledger** collaborated with the government agency Cooperative Research Centre for Developing Northern Australia (CRCNA) to test holding the Mareeba-Dimbulah water supply system in far north Queensland on a public blockchain. In this region alone, there are *"nine pieces of legislation and operational plans that govern the water business, multiple agencies that regulate and operate the water system, and 2,000 water users".*[59]

Water Ledger was built on the Ethereum blockchain and uses the ERC 1753 - Smart Contract Interface for Licenses[60] standard to manage the issuance of licenses and permits, which until now were entirely manual, paper-based, and scattered across multiple entities.

These licenses have been dematerialized as smart contracts* allowing everyone to interact within a peer-to-peer water trading market. The time to complete a transaction has been reduced from 90 days to less than 7 days after the implementation of Water Ledger.

In addition, by using the ERC 1753[61] standard for smart contracts*, the rules for allocating water, especially when it runs out, can be updated in real time by public authorities to *"prioritize it for domestic use"*[62] explains Katrina Donaghy, CEO of Civic Ledger.

57 "Member Spotlight: Civic Ledger, Digitally Transforming Water". Jun 10 2020 Fintech Australia Newsroom Spotlight https://www.fintechaustralia.org.au/member-spotlight-civic-ledger-digitally-transforming-water/
58 "Blockchain and the Built Environment", February 2019 Version 1.2, https://www.arup.com/
59 "How distributed ledger technology is revolutionizing water markets", Katrina Donaghy, Fraser MacLeod, WeForum, Jun 22 2021, https://www.weforum.org/agenda/2021/06/distributed-ledger-technology-water-markets
60 "EIP-1753: Smart Contract Interface for Licences", Ethereum Improvement proposals, retrieved May 16 2022, https://eips.ethereum.org/EIPS/eip-1753
61 This Ethereum Improvement Proposal (EIP) proposes an Ethereum standard for licensing, permits and grants (Licenses). https://eips.ethereum.org/EIPS/eip-1753
62 "How distributed ledger technology is revolutionizing water markets", Katrina Donaghy, Fraser MacLeod, WeForum, Jun 22 2021, https://www.weforum.org/agenda/2021/06/distributed-ledger-technology-water-markets

ISSUES AND QUESTIONS

Some 63 active initiatives to date are explicitly involved in the fight against global warming and the preservation of the environment. This means that taking an interest in blockchains and the environment is not an oxymoron. The proof-of-work consensus mechanism*, used by first generation blockchains such as Bitcoin or Ethereum, relies on an energy expenditure to secure transactions on the network.

Blockchain initiatives, such as **Toucan Protocol** or **KlimaDAO**, are thus fluidifying **traditional voluntary carbon markets,** which have been subject to a number of criticisms.[1] [2]

Indeed, the issuers of carbon credits, such as Vera or Gold Standard, do not offer a sufficiently robust methodology to demonstrate without ambiguity the real impact of projects that allow them to generate carbon credits. The sustainability of carbon sequestration projects over long periods of time, sometimes up to 20 years,[3] is also subject to criticism.

For example, Reducing Emissions from Deforestation and Degradation REDD and REDD+ were invented and launched in 2011, under the impetus of the UN, to finance conservation projects in developing countries, with the aim of mitigating climate change.[4] Yet, as Greenpeace explains *"avoided deforestation programs generate and sell carbon credits based on the amount of deforestation they claim to prevent. To calculate these carbon*

1 "Carbon offsets used by major airlines based on flawed system, warn experts", Patrick Greenfield, May 4,2021. https://www.theguardian.com/environment/2021/may/04/carbon-offsets-used-by-major-airlines-based-on-flawed-system-warn-experts

2 "Carbon offsets are going primetime and they're not ready" Tim McDonnell, May 20, 2021. https://qz.com/2009746/not-all-carbon-offsets-are-a-scam-but-many-still-are/

3 "How our partner Wildsense monitors carbon sink restoration from space", CarbonABLE, June 3, 2022.https://carbonable.medium.com/how-our-partner-wildsense-monitors-carbon-sink-restoration-from-space-86e3a4ca759

4 REDD+ relies on policy approaches and a system of positive incentives to reduce emissions from deforestation and degradation (REDD) and to help conserve existing forest carbon stocks, manage forests sustainably and increase forest carbon stocks (+) in developing countries. Source: FLEGT-REDD+ Interactions Briefing Note No. 2 January 2011. Proforest with contributions from officials from the European Commission and Member States, the Government of Norway, and representatives of FCPF and UN-REDD. https://europa.eu/capacity4dev/file/10546/download?token=RvEfqdVx

savings, they try to predict how much deforestation would occur if the project did not exist".[5] These hypothetical calculations prove to be very fragile when it comes to verifying the validity of these carbon offsets in the field. In the meantime, carbon credits are generated and sold to companies, which calls into question the very effectiveness of this type of mechanism. The most recent analysis on the subject, carried out by Unearthed, the investigative arm of Greenpeace, together with the British media The Guardian and the German NGO SourceMaterial, analyzed *"ten projects for reduced deforestation offsets that major airlines rely on as part of their emission reduction commitments and that are certified by Verra, the largest issuer of carbon credits in the world",*[6] based on expert analysis, project documentation and satellite analysis of deforestation in and around the projects supported by British Airways, easyJet and United Airlines. Their verdict was very mixed, to say the least.[7]

If the interest of tokenizing carbon credits from international registries such as Vera or Gold Standard is to include them in decentralized finance, some blockchain projects, such as **Nori**, aim at verifying in a finer way, on the ground, the efficiency of the latter, in particular through the use of decentralized oracles such as **Chainlink**.

The promise of these initiatives concerns the activities of regenerative agriculture, afforestation or reforestation, such as **Open Forest Protocol**, **GainForest** or **Eco-Cacao** via **Regen Network**, surely simpler to measure and quantify than deforestation avoidance projects. These projects are in line with the carbon market and are therefore not exempt from the criticisms leveled at those financial mechanisms. Could the use of distributed and public registries really improve on the deficiencies of carbon markets?

5 "Top airlines' promises to offset flights rely on 'phantom credits'", Joe Sandler Clarke, Luke Barratt, May, 4, 2021. https://unearthed.greenpeace.org/2021/05/04/carbon-offsetting-british-airways-easyjet-verra/
6 *Ibid.*
7 *Ibid.*

Other projects, particularly those related to the water market, such as those in Australia, demonstrate the effectiveness of setting up a distributed registry in a complex market with many participants. It brings more transparency, eliminates intermediaries and makes exchanges more fluid. The initiatives carried out in the field of public services (see chapter “Government and Democracy”) function in the same way.

Once again, it is not a matter of adding a blockchain dimension to projects to make them more efficient, but of examining how the use of a common register can overcome the asymmetry of information between the various stakeholders in complex value chains. As blockchains are a tool whose value depends only on the use that is made of it, none of these projects can guarantee the veracity and accuracy of the information shared in a distributed registry. The limitations relative to the quality of the data may dictate the usefulness or otherwise of these projects whose lack of maturity does not allow us to yet say if they are a new “greenwashing” or if they are the beginnings of more profound changes contributing to climate resilience.

SUPPLY CHAIN & LOGISTICS

SUPPLY CHAIN AND LOGISTICS

Number of projects in the directory: 86

Number of active projects: 60

Name of active projects: Ambrosus ; Arc-net ; Arianee ; Aware ; BanQu ; Blockfreight ; CargoChain ; Chainvine ; Chronicled ; Circularise ; CircularTree ; Clara Diamond Solutions ; CobaltBlockchain ; Compellio Registry ; Decapolis ; Devery ; Dibiz ; Emurgo ; Everledger ; Evertrace ; Faircoin ; FAO charcoal in Ivory Coast ; FAO farming in Papua New Guina ; Forest Stewardship Council (FSC) ; Gaiachain ; "GemFair project" ; Genuine Way ; KYG Trade Foundation ; Minexx ; Mintrax ; Morpheus ; NutraSign ; Nyala ; Oceanus Foundation ; Open Packaging Network OPN ; OriginTrail ; OURZ ; Ownest ; Provenance ; RCS Global and the Better Sourcing Program ; Re | Source ; Realchain ; Reason ; Retraced ; S3FOOD ; Sandblock ; ScanTrust ; Skuchain ; SUKU ; TextileGenesis ; The Egyption Cotton project - UNECE & UNIDO ; The Other Bar - UN blockchain chocolate ; Tracr ; TradeLens (IBM and Maersk) ; Transparency One ; Transparent Path ; VeChain foundation ; VerifiK8 ; Wave ; Yave Blockchain Platform ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

Supply chain traceability is, according to the Food and Agriculture Organization of the United Nations (FAO), "*the ability to trace the history, application or location of an entity by means of recorded identifications*[1]". Today, according to the United Nations Economic Commission for Europe (UNECE[2]), all companies whose activities depend on international supply chains are confronted with recurring issues, including (1) Being able to prove the origin of goods, (2) Optimizing customs delays, (3) Overcoming lack of supply chain transparency, (4) Ensuring supply chain resilience, (5) Managing errors in payment processing and auditing, (6) Thwarting data-driven scams, (7) Resolving disputes, (8) Depending on a "flow of information" that stops at the point of sale.

1 "Blockchain application in seafood supply chains.", Francisco Blaha & Kenneth Katafono, FAO Fisheries and Aquaculture Circular No. 1207. Rome, FAO, 2020, https://doi.org/10.4060/ca8751en

2 United Nations Economic Commission for Europe - UNECE is one of the five regional commissions of the Economic and Social Council of the United Nations, established in 1947 to promote economic cooperation among member states.

In addition to an economic approach, a supply chain is also interpreted according to its social and environmental externalities, ensuring that child labor is banned, that the members of the first part of the supply chain, who are most of the time the most vulnerable, receive a decent wage. As for the environmental dimension, it covers several issues including waste, pollution, carbon footprint and illegal trade of products. Supply chain actors are increasingly aware of the climate issues inherent in the transport of goods and commodities. However, the environmental impact of a supply chain relies on the sharing of a certain amount of information, both financial and non-financial, which only interoperability could guaranteeoverall consistency. Climate change issues should encourage all players to comply with common standards, stimulating "coopetition", a mixture of cooperation and competition that goes beyond the interests of each entity taken separately.

Sustainable Development Goal 17 incorporates international trade as part of the capacity building of the Global Partnership for Sustainable Development. It aims to "*promote a universal, rule-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through negotiations under the Doha Development Agenda*".

The implementation of the Doha Development Agenda is linked to several other Sustainable Development Goals, including sustainable agriculture (SDG 2), decent work (SDG 8), sustainable consumption and production (SDG 12), sustainable use of marine resources (SDG 14), protection of wildlife (SDG 15), justice and peace through effective, accountable and inclusive institutions (SDG 16).

Under the influence of digital technology and the Internet of Things (IoT), logistics flow management now relies on a wide range of tools for planning, tracking, manufacturing, inventory optimization, transportation and warehousing. As well as the management of related data, the ultimate goal for a company is to **follow as closely as possible, ideally in real time, the perpetual movement of data related to its activity.**

The promise of blockchains is to provide "*a decentralized database containing sequential, cryptographically linked blocks of digitally signed asset transactions, governed by a consensus model*[3] ", thus enabling the management of information and transaction flows in a secure and automated way between a network of actors. Its application in the logistics and traceability sector might seem obvious. Modern logistics chains involve more and more actors who do not know each other but interact constantly, which is an appropriate context for managing the trust

3 "Conceptualizing blockchains: characteristics & applications", Karim Sultan, UmarRuhi, Rubinar Lakhani, 11th IADIS International Conference Information Systems, 2018.

of information recorded at each stage of their interactions through a distributed ledger.

Today, an international supply chain remains opaque to many of the companies in its supply chain. As Susanne Köhler, from the University of Aalborg in Denmark, explains, "*Companies often do not know their Tier 3 or Tier 4 suppliers, with limited visibility beyond the first tier.*[4]

The implementation of distributed ledgers in a supply chain aims to guarantee the transparency and integrity of information and data provided by each of the actors in the supplychain. Once recorded, this data cannot be modified, and itsaccess for each of the stakeholders becomes easily verifiable and traceable. Distributed ledgers are an alternative to data systems organized in silos, where each actor holds complex, incomplete and time-consuming information to share or transfer with other parties.

At least, this is the promise of many initiatives related to traceability in industrial sectors as varied as mineral extraction (diamonds, rare earths, cobalt, tantalum etc.), forestry, cocoa, coffee, cotton crops or even the traceability of agricultural and fishery products (see Chapter "Agriculture and Food").

Supply chain management blockchain projects such as **Emurgo**, the commercial branch of the public blockchain **Cardano**, founded in Singapore in June 2017, **Ambrosus**, **CargoChain**, **CargoX** or even **Skuchain** propose to reduce and digitalise administrative formalities. They are also aligned with the United Nations Commission on International Trade Law (UNCITRAL) Model Law on Electronic Transferable Documents of July 13, 2017, which enables "*the legal use of electronic transferable documents at the national and international levels.*" This model law in fact provides for a principle of technological neutrality "*which allows the use of different models that may be based on a registry, tokens, a distributed registry or other technology*[5] ".

According to Eric A. Caprioli, attorney[6], "*when it comes to ledgerstoday, the distributed ledger solution embodied by blockchain technology, seems the most relevant means in operational terms since it fulfills reliability and control functionalities"*. In October 2021, the G7 countries have in fact committed to changing their legislation[7] and were aligned with the UN Commission's Model Law on Transferable Electronic Records. But the transition from paper to a decentralized registry, or even the emergence of Decentralized Autonomous

4 "Unfinished Paths-From Blockchain to Sustainability in Supply Chains.", Susanne Köhler, Massimo Pizzol and Joseph Sarkis, Frontiers in Blockchain, 2021
5 "UNCITRAL Model Law on Electronic Transferable Documents," United Nations Commission on International Trade Law, United Nations Publication July 8, 2017, https://uncitral.un.org/fr/texts/ecommerce/modellaw/electronic_transferable_records
6 Eric A. Caprioli, Attorney at Law, Paris, Doctor of Law Law firm member of the JurisDéfi Network
7 "From electronic transferable documents to blockchain," Usine-digitale.fr, December 9, 2021, https://www.usine-digitale.fr/article/des-documents-transferables-electroniques-a-la-blockchain.N1167847

Organizations (DAOs*) on a global scale is still far off.

Agriculture & Fishing

Numerous blockchain initiatives aim to ensure transparency in supply chains, particularly in the traceability of food, agricultural or fishing products, or in the orchestration of agricultural market mechanisms. There are also projects in the field of insurance related to agriculture, such as Etherisc (see chapter "Peer-to-peer electronic cash system and programmable money").

Founded in 2016, **TE-FOOD** is based in Budapest, Hungary, and Albstadt, Germany. The company claims "*more than 6,000 client companies, 10,000 trained supply chain workers and 400,000 business transactions per day*[8] ". TE-FOOD is developing an ecosystem *"integrating supply chain companies, consumers as well as authorities to improve food safety, eliminate food fraud and reduce costs for supply chain companies."* The company has developed a public permissioned blockchain*[9] composed of about 100 nodes spread across different countries.

The blockchain is called permissioned because only TE-FOOD's client companies are allowed to write data to the public blockchain. They also define the information they wish to make public, for example to the consumer, while continuing to benefit from a private business environment within a transparent and secure ecosystem.

8 "What can you achieve with TE-Food?", TE FOOD, retrieved May 31 2022, https://te-food.com/
9 Words marked with an asterisk refer to the glossary.

TE-FOOD and Covid 19 management[1]

In 2020, TE-FOOD partnered with Eurofins and GE Aviation to create TrustOne on their public blockchain. Eurofins is an international medical testing services group with 800 laboratories in 50 countries around the world.
Eurofins has deployed to its laboratories and corporate clients in charge of the vaccination of their employees, a traceability solution of the complete process, from the appointment to the test results of Covid 19.

1 "TE-FOOD, Eurofins, and GE Aviation cooperate to offer end-to-end Covid-19 testing process solution for corporate customers," TE-FOOD, Sep 14 2020, Medium, https://medium.com/te-food/te-food-eurofins-and-ge-aviation-cooperate-to-offer-end-to-end-covid-19-testing-process-solution-9956b69f388c.

In concrete terms, a TE-FOOD blockchain client company uniquely identifies each of its products in accordance with the international nomenclature, managed globally by GS1[10] . The data is then captured during the production process and recorded as it happens in the public blockchain. Some nodes of the TE-FOOD blockchain are maintained by supply chain actors and others by consumer communities. One of the major challenges in setting up a food traceability project is training producers, breeders and farmers in the digital tools, which requires real ease of use. But according to Erik Árokszállási, CEO of TE-FOOD, "*blockchain technology is transparent to the user, so it is not a barrier to adoption. Thousands of farmers use it every day, many of them without knowing what the underlying technology is*."

Food traceability is not only about the logistical tracking of agricultural commodities harvested in the Southern Hemisphere to consumers in the Northern Hemisphere. Intraregional trade in Africa plays an important role in reducing market volatility and improving food security[11] .

In Kenya, **Twiga Foods,** which means giraffe in Swahili**,** is another case of food traceability addressing the fragmentation of retail markets, 90% of which are small retailers and informal middlemen. One consequence of the fragmentation of these retail markets is that a ton of tomatoes harvested in Kenya costs about

10 GS1 is the global organization for the standardization and normalization of languages used in the supply chain and trade, such as the one- and two-dimensional barcode.
11"OECD and FAO Agricultural Outlook 2016-2025," OECD & FAO, Annual ISSN: 19991150, 2016, https://doi.org/10.1787/19991150

$100 in the United States and $400 in Kenya[12] . The poorest households spend up to 50% of their income on food, while the average American spends 6.4%[13] . This was the starting point for Twiga Foods in 2014 to "build *a closed ecosystem for retail in Africa, focused on affordable access to food and groceries in cities*[14] ".

Twiga Foods has developed a business-to-business trading platform aimed at simplifying the supply chain between fresh produce growers, Fast Moving Consumer Goods manufacturers and retailers, cutting out many middlemen to reduce the cost of food for consumers.

How Twiga Works[15]?

On the supply side, the biggest problem farmers face is getting their commodities to market, particularly because of their dependence on informal intermediaries in the supply chain. Unscrupulous brokers take advantage of these difficulties by offering farmers below-market prices for their products or refusing to negotiate with them during periods of oversupply. Twiga's proposal is to offer farmers a guaranteed market and fair prices. Twiga deals directly with farmers to meet retailer demand and collects produce directly from the farms. Farmers are paid *via* the M-Pesa mobile money platform within 24 hours of collection. According to Njonjo[16] , Twiga has reduced typical post-harvest losses in Kenya from 30% to 4% for produce sold *through* the Twiga platform.

On the demand side, Twiga registers merchants in Nairobi, who then place orders with a sales representative or directly on the Twiga app. Twiga ships orders *via* its distribution vehicles within 24 hours. To optimize delivery, Twiga maps its vendors using a geographic information system (GIS) and relies on a distribution platform with an artificial intelligence algorithm to know who is

12 "Kenya's Twiga raises $50M to scale food solutions across Africa", Tage Kene-Okafor, techcrunch.com, Nov 1 2021, https://techcrunch.com/2021/11/01/kenyas-twiga-raises-50m-to-scale-affordable-food-solutions-across-africa/
13 "Consumer Expenditures-2020," U.S. Bureau of Labor Statistics, Economic News Release, retrieved May 11 2022, https://www.bls.gov/news.release/cesan.nr0.htm
14 "Revolutionizing African Retail", Twiga, retrieved May 11 2022, twiga.com
15 " How Twiga Foods reduces the price of food in Nairobi using technology ", Twiga, Lincoln, November 1, 2021, retrieved May 11, 2022, https://twiga.com/?p=3546
16 *Ibid.*

ordering, where the vendors are located, what the road conditions are, and how best to organize deliveries to maximize efficiency. By digitizing and creating a record of all transactions, Twiga is also able to offer access to credit products through third parties, whether to farmers or vendors.

IBM has been tasked with developing the business-to-business platform based on the Hyperledger Fabric blockchain, as well as machine learning and data processing technologies including the loan application process used by sellers applying *via* their mobile devices.

One of the machine learning algorithms is used to predict the creditworthiness of sellers "*giving lenders the confidence they need to make microloans to small businesses*[17] " explains Isaac Markus, a researcher at IBM who participated in the project.

The processes of loan application, acceptance and repayment are recorded and processed *through* Twiga Foods' blockchain by greatly simplifying the administrative part. The company, now in its eighth year of operation, has become the largest buyer of fresh produce in Kenya, serving more than 5,000 farmers and 35,000 merchants.

Twiga Foods has raised a total of $157.1 million in 19 rounds of financing, most recently in November 2021[18] , including expansion into West Africa during 2022.

In the area of food traceability alone, we have referenced in the Positiveblockchain.io database some 71 projects since 2018, of which 34 are active to date and have dedicated an entire chapter to this topic[19]

17 "IBM Helps Kenyan Agriculture Flourish On Twiga Blockchain", Steve Kaaru, Cryptobriefing, Dec 15 2018 https://cryptobriefing.com/ibm-kenya-agriculture-twiga-blockchain/
18 "Twiga Foods," Crunchbase, retrieved May 11 2022, https://www.crunchbase.com/organization/twiga-foods/company_financials
19 See chapter "Agriculture & food".

Raw materials

The traceability of raw materials is the subject of numerous experiments by organizations of all types, from small start-ups to large, well-established companies, sometimes with the help or support of NGOs or international organizations, particularly in the field of mineral extraction, timber production, cocoa, coffee or cotton growing.

Minerals

Since the mid-2010s, the mining industry has turned its attention to digital-based certification technologies in mineral supply chains, "*adding to a plethora of regulatory instruments and governance initiatives meant to introduce accountability into an industry tarnished by human rights abuses, child labor and minerals used to fund conflict*[20] ."

Far from the image one might have of mining companies, they are first and foremost *data-driven* companies, "*geological and economic data to determine if the operation is worthwhile; environmental data to monitor and mitigate impact; and financial data to keep investors informed*[21] ."

Today, this largely disparate data is processed manually through one or more Enterprise Resource Planning (ERP) programs. Some of it is recorded in Excel spreadsheets or even copied from paper at irregular intervals and depending on the arrival of external auditors, who are brought in to check the consistency of the information.

The value proposition of implementing a public blockchain to track a mining activity is threefold. Data is shared in real time between all actors involved in the supply chain. It is recorded on a distributed ledger and can no longer be modified, which makes it possible to identify human error and combat fraud. Finally, the implementation of a blockchain optimizes costs and time by eliminating the need for a trusted third party to verify the data.

BetterChain, **Circulor**, **Clara Diamond Solutions, CobaltBlockchain, Everledger**, **GemFair project, Minexx**, **Mintra, Re | Source, Tracr** or **RCS Global** are some of the many blockchain initiatives that aim to make the activities of mining industries transparent.

However, it seems that most of these projects retain centralized governance. The blockchain being deployed is more about optimizing existing ERP software than about truly creating a distributed ecosystem of public data, specific to an industry. In the energy sector, the Energy Web Foundation has already opted for this approach (see "Energy" chapter).

20 "Governing extractive industries. Politics, histories, ideas", Abdul-Gafaru Abdulai, Anthony Bebbington, Denise Humpfreys Bebbington, Marija Hinfelaar, Cynthia Sanborn (Eds.), Oxford Univ. Press, Oxford , 2018.
21 "Data-driven, data-dependent: Blockchain in the Mining Industry," Christian Ecker, MineSpider, Jun 8 2021, minespider.com/blog,

Many projects involve developing a private blockchain, following the example of **Mimosi (PeerLedger)** or **Circulor.** Mimosi has been working since 2016 to create a traceability system combining a *cloud* solution whose data is stored in a private blockchain built with Hyperledger Fabric*.

Artificial intelligence, geographic location data (GPS) and components of the Internet of Things (IoT), are associated with it so that stakeholders, on the ground, interact through web interfaces. Being open only to those who set it up, the use of a private blockchain is mainly used to optimize costs and time.

Circulor, founded in 2017 conducted an initial pilot on the traceability of tantalum from Rwanda in 2018, in partnership with the Rwandan Mining, Oil and Gas Council, and has since developed an information system based on a private, permissioned blockchain. Since then, Circulor has grown to provide "*full transparency on the carbon flow of materials throughout the supply chain, from raw materials to the manufacturers themselves*[22]*".*

Doug Johnson-Poensgen, CEO of Circulor explains that "*many automakers are using our technology to demonstrate responsible sourcing of critical raw materials, including nickel (associated with deep-water tailings in the Pacific Ocean) and lithium (which raises concerns about water sources in arid places like the Chilean Atacama Desert).*" The solution interfaces *via* APIs* with the software of client companies, including BHP, FMG, SGS, Volvo Cars, Daimler, Jaguar and Land Rover[23] .

De Beers, the South African diamond conglomerate says it has registered more than 400,000 diamonds on a private permissioned blockchain[24] developed on Ethereum called **Tracr**, which has about 30 participants from the diamond industry. The platform records "*a diamond's size, color, clarity and carat, then tracks it through the supply chain*[25] ," assuring their customers "*the origin and authenticity of the stone with a simple scan as it is mined, cut, polished and sold*[26] ."

22 "Tracing the supply chain with Circulor", Kim Zou and Sophie Purdom, Climate Tech VC, Jun 11 2021 https://climatetechvc.substack.com/p/-tracing-the-supply-chain-with-circulor?s=r
23 "Trafigura and Circulor to provide carbon emissions tracking and traceability via blockchain to nickel and cobalt supply chains," Circulor, retrieved May 11 2022, circulor.com
24 "Blockchain technology to power De Beers' diamond production," Gareth Jenkinson, May 06, 2022. https://cointelegraph.com/news/blockchain-technology-to-power-de-beers-diamond-production
25 Forbes Blockchain 50 2022, Tracr, Feb 8, 2022. https://www.forbes.com/sites/michaeldelcastillo/2022/02/08/forbes-blockchain-50-2022/?sh=40f8e0b831c6
26 *Ibid*.

Minespider has been developing a permissioned public blockchain since 2017[27] , which specifically addresses commodity supply chain traceability. The system uses the Ethereum public blockchain to maintain the transaction record.

As for legal and contractual documentation, to avoid keeping it in a centralized database, Minespider uses the decentralized file storage solution IPFS*.

Three types of digital certificates are created, depending on whether the data is to be public, available only to members of the supply chain, or private between the customer and the company[28].

The system would allow it to be used to "*communicate critical data on provenance, worker safety, carbon emissions, water use, and any other important data point, all without centralized control of the data*[29] ."

This is a way to comply with the European regulation applicable since January 2021, also known as the Conflict Minerals Regulation, which imposes on importers of tin, tungsten, tantalum and gold (3TG) a duty of care to verify that the minerals do not come from a geopolitically unstable area[30] .

But by the admission of many in the industry, the interest in these **blockchain initiatives in mining is still very immature**.

In April 2021, at the 14*the* annual OECD Forum on Responsible Mineral *Supply Chains,* many participants will have remembered[31] that the development of exemplary, responsible and transparent supply chains **requires all players to adhere to the same data ecosystem rather than each working on their own on a closed proprietary system, even if it is or tries to be interoperable with the neighbor's.**

27 "Data-driven, data-dependent: Blockchain in the Mining Industry", Christian Ecker, Minespider, Jun 8 2021 https://www.minespider.com/blog/data-driven-data-dependent-blockchain-in-the-mining-industry
28 "Minespider partners with Google for tin blockchain traceability," Ledger Insights, November 23, 2020, https://www.ledgerinsights.com/minespider-partners-with-google-for-tin-blockchain-traceability/
29 "Lead the Shift to sustainable supply chains," MineSpider, retrieved May 11 2022, https://www.minespider.com/
30 "Minespider secures EIT RawMaterials Booster funding to develop responsible mineral tracking," Eit Raw Materials, Sep 22 2020, https://eitrawmaterials.eu/minespider-secures-eit-rawmaterials-booster-funding-to-develop-responsible-mineral-tracking/
31 "Recap: OECD Forum on Responsible Mineral Supply Chains", Peerledger, retrieved Apr 27 2022, https://www.peerledger.com/

In particular, the Responsible Minerals Initiative[32] (RMI) drafted the "RMI Blockchain Guidelines"[33] , updated in 2020, back in 2018 to guide their members towards implementing a blockchain to track their business. Among other things, the document advocates that "*the blockchain-based solution must be decentralized, with the term* 'decentralized' *referring to the absence of a single location where data is aggregated or controlled.*"

However, private and permissioned blockchain projects boast of participating in the development of the RMI Blockchain Guidelines, which does not initiate major innovations given the centralized nature of the experiments, which are also quickly confronted with interoperability problems.

As researchers Filipe Calvao and Matthew Archer explain, these blockchain initiatives would even tend to "*accentuate the gap between the technological aspiration of fully digitized supply chain traceability information, driven by multinationals, and the working conditions of small miners and local and national businesses, left largely outside the scope of these initiatives for reasons of political expediency, economic cost or technological design*"[34] .

These same researchers looked at the traceability of cobalt in the Democratic Republic of Congo (DRC), which alone holds 70% of the world's reserves and whose extraction is carried out by both industrial and artisanal mines.

Their finding is that there is no local political will to implement a traceability system, especially in artisanal mines.

Indeed, "*as artisanal miners are not paid a salary and are paid for mined ore according to prices set by the mining companies, the costs of digital monitoring and certification are potentially shifted to the miners themselves.*" Furthermore, these blockchain initiatives do not address the potential corruption issues of feeding false information into such a system.

Finally, there is reportedly a "*general suspicion of any attempt to track and digitally record cobalt transactions*" on the part of artisanal miners.

32 "Founded in 2008 by members of the Responsible Business Alliance and the Global e-Sustainability Initiative, the Responsible Minerals Initiative has become one of the most widely used resources for companies in a variety of industries interested in responsible mineral sourcing issues in their supply chains. More than 400 companies and associations from over 10 sectors now participate in RMI, and we regularly collaborate with other complementary programs and initiatives in this area." *In* "About Responsible Minerals Initiative," Responsible Minerals Initiative, retrieved May 11 2022, https://www.responsiblemineralsinitiative.org/about/rmi-initiative/

33 "Blockchain Guidelines," Responsible Minerals Initiative, retrieved May 11 2022, http://www.responsiblemineralsinitiative.org/media/docs/RMI%20Blockchain%20Guidelines%20-%20Second%20Edition%20-%20March%202020%20FINAL.pdf

34"Digital extraction: Blockchain traceability in mineral supply chains," Matthew Archer, Filipe Calvão, Political Geography Volume 87, 2021, https://www.sciencedirect.com/science/article/pii/S096262982100041X?via%3Dihub

The main reason for this failure is that these blockchain initiatives, developed by startups or industrial groups, are essentially aimed at the consumer.

No project really changes the current paradigm of mining, involving artisanal mines, all artisanal miners and their working conditions, as well as the social and environmental impacts, especially on communities living around the extraction sites.

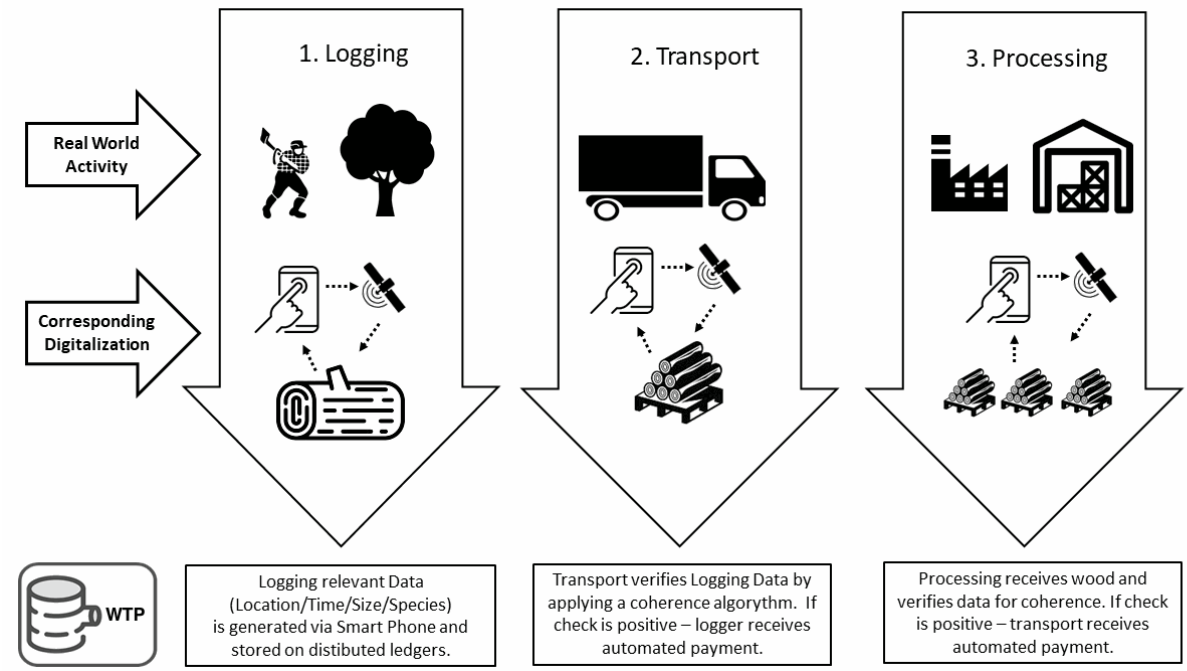
This issue is also relevant to the traceability of agricultural chains, which focus on the agricultural product rather than the producer or farmer, who is the first in the supply chain. The researchers conclude that "***the narrative of blockchains*** *as open, democratic platforms that promote transparency in conflict-ridden global commodity chains* ***diverges from the actual blockchain projects*** *developed by the mining industry to meet growing consumer demand for traceability*[35] ."

Timber

The field of timber production and forest preservation is also the subject of blockchain initiatives, notably in the Peruvian Amazon region with **Wood Tracking Protocol**, or in Ivory Cost, with **Charcoal Trace**.

Ten years ago, the World Bank estimated that "*80% of Peru's timber exports are illegal*[36] " in a country 53% covered by forests, the majority of which are in the Amazon region, classified as primary forest. The Defensive Driving Center (DDC), based in Peru since 2009, is a training center approved by the National Security Council of the United States offering international certificates. In 2018, it carried out a proof of concept as well as a blockchain computer prototype with the objective of "*digitizing the paper trail of wood processing operations in the Amazon region and putting it on a public blockchain*": Wood Tracking Protocol (WTP).

35 *Ibid.*
36 "In pictures: Illegal logging in Peru," BBC, September 4, 2014, https://www.bbc.com/news/world-latin-america-28926270



Wood Transfer Protocol Project
Source : WTP, " Our Solution ", https://wtp-project.com/solution.php

How Wood Tracking Protocol works[37]

The project combines features offered by mobile devices (such as smartphones and tablets) and blockchain technology to support wood traceability in the Peruvian Amazon region.

Wood Tracking Protocol offers supply chain actors (loggers, transporters...) an application that collects forest relevant data that will then be managed and processed on a platform. Typically, the data can be the geographical parameters of a logging license, data on the species or size of a tree to be harvested or an image integrating a timestamp and GPS data showing an operation along the wood processing chain. Users of the application, the loggers, connect to the Wood Tracking Protocol platform where identity validation is done by verifying the phone number. Once the user is validated by Wood Tracking Protocol, he will be able to interact with the platform where the information collected will be recorded in the blockchain used.

The app then allows its users to document their work (using photography, GPS and other features on a mobile device) and store that information sequentially

37 "Our solution", Wood Transfer Protocol Project, retrieved May 11 2022, https://wtp-project.com/solution.php

and tamper-proof on a blockchain. The project complements real-world tracking by attaching a unique digital history, including GPS route and time, to a tree or load of wood. This is how Wood Tracking Protocol can reduce the risk of the same tree or load of wood being unrecorded multiple times when tracked by paper.

Wood Tracking Protocol initially developed its platform based on the public Ethereum blockchain before switching to a private blockchain due to, according to the 2021 NAATBA report "*current scalability limitations (storing large data on Ethereum in March 2021 is cost prohibitive) and the energy-intensive use of Ethereum's Proof of Work consensus mechanism*[38]".

Charcoal Trace

In Ivory Coast, the production of traditional charcoal and firewood has long been associated with problems of deforestation and land degradation.

According to the United Nations Development Program (UNDP), it is used as the main source of domestic energy by 47% of households in urban areas. However, according to the Société de Développement des Forêts (SODEFOR), an Ivorian state-owned company created in 1966 and attached to the Ministry of Water and Forests and the Ministry of Economy and Finance, "*nearly 300,000 hectares of forest disappear annually due to the illegal overexploitation of wood used for the production of charcoal and the export of precious wood (Tek, Afrormosia and Bete)*". In addition, *"the charcoal and firewood market is largely informal and unorganized and therefore easily penetrated, and is often subject to problems of corruption and pressure between actors*".

Based on this observation, since 2008, an Ivorian women's association, MALEBI, has been involved in the production and sale of sustainable charcoal.

After signing two partnership agreements with SODEFOR in 2011 and 2018, the Association manages the classified forest of Ahua with an area of 4,500 ha and claims 150 ha of reforestation,

38 "Blockchain for Climate Action and the Governance Challenge," INATBA's 2021 report, https://inatba.org/reports/climate-action-governance-challenge/

carried out in collaboration with the local communities, allowing them to produce and sell a sustainable charcoal.

One of the main challenges facing MALEBI is that "*small-scale producers who attempt to manage forests legally and sustainably to produce charcoal find it difficult to compete with those who extract resources informally and unfairly and do not contribute to management costs*."

Source: Delphine Ahoussi, President of the Association of Women Charcoal Producers and Vendors (MALEBI) - https://www.flickr.com/photos/faoforestry/50566430711/in/album-72157716747275473/

The production cost of charcoal from MALEBI cannot compete with illegal charcoal exploitation. To better value this sustainable exploitation, MALEBI has been running a blockchain initiative, **Charcoal Trace**, since 2020 with two partners. **Resource Extraction Monitoring (REM)**, a technical partner, a British non-profit organization founded in 2003 and specializing in "*independent monitoring of law enforcement and governance for activities related to the extraction and management of natural resources*[39]," as well as **Gaiachain**, a British organization founded in 2018 whose mission is to "*develop traceability and payment solutions to support deforestation-free supply chains, particularly those that rely on small farmers.*"

The initiative was funded by the Food and Agriculture Organization of the United Nations[40] (FAO), the Swedish International Development Cooperation Agency, the UK Foreign, Commonwealth and Development Office and the European Union.

Charcoal Trace is a basic mobile and web application that allows to "*trace the product and record essential documents such as the charcoal production permit, receipts for payment of royalties per bag and travel books signed by Water and Forestry Agents, but also prevent abusive removal of permits or paper*

39 "Few Words about us", Resource Extraction Monitoring, retrieved May 11 2022, https://rem.org.uk/
40 "Development of a pilot sustainable and legal charcoal traceability system based on blockchain technology", FAO-EU FLEGT Programme, 2019-2021, https://www.fao.org/in-action/eu-fao-flegt-programme/our-projects/en/#/web/project/5b3a4e155bb93e49b83bf5ef

authorizations during controls by some agents on the road[41]". The proof of concept was first developed on a private blockchain, Hyperledger, before being ported to a public blockchain. The application thus allows coal to be traced from the production site to the points of sale.

The data recorded in the blockchain includes the number of trees cut and their species as well as their GPS coordinates along the way, the number of bags of charcoal produced, sold and received as well as the legal documents. This involves both regulatory authorities, government, certifiers as well as producers, processors and buyers.

In addition, a premium charcoal market is developing in Abidjan and, according to the German International Development Cooperation Agency (GIZ), "more *and more buyers are looking to source quality charcoal in the food and cosmetics sector, either at an individual or corporate level*[42]".

Cocoa

If the promise of blockchain technology is to be able to offer transparency "*from farm to fork*" according to the now established marketing expression, some projects are concerned with ensuring that the first in the production chain receive a decent wage (SDG 8[43]).

This is what the company **Koa**, based in Switzerland and Ghana, claims to have done in March 2022, having paid 2,250 small Ghanaian farmers 263,000 euros and having also avoided 390 tons of food waste[44] .

Koa[45] trains cocoa farmers to process the previously discarded cocoa bean pulp. This allows them to earn extra income and be paid promptly after the production process. Koa has developed a solar-powered "mobile community processing unit" (see image below) that extracts the cocoa pulp right in the farmers' communities, next to the cocoa plantations.

41 "Blockchain technology for good governance of charcoal in Ivory Coast," Eulalie Guillaume, Pilot Project Executive Summary, April 2021.
42 "Ivory Coast", GIZ, retrieved May 11 2022, https://www.giz.de/en/worldwide/346.html
43 SDG 8 Target 3: Promote development-oriented policies that foster productive activities, decent work, entrepreneurship, creativity and innovation, and stimulate the growth of micro, small and medium enterprises and facilitate their integration into the formal sector, including through access to financial services.
44 "Can Blockchain Fix the Chocolate Industry's Labor Issues?", Jill Ettinger, Mar 24 2022, https://www.greenqueen.com.hk/blockchain-cocoa-labor-issues/
45 "Koa taking transparency to the next level with seedtrace", Seed Trace, retrieved May 11 2022, https://seedtrace.org/case-study-with-koa

Mobile community treatment unit - Koa, in Ghana
Source: Koa, https://koa-impact.com/production/

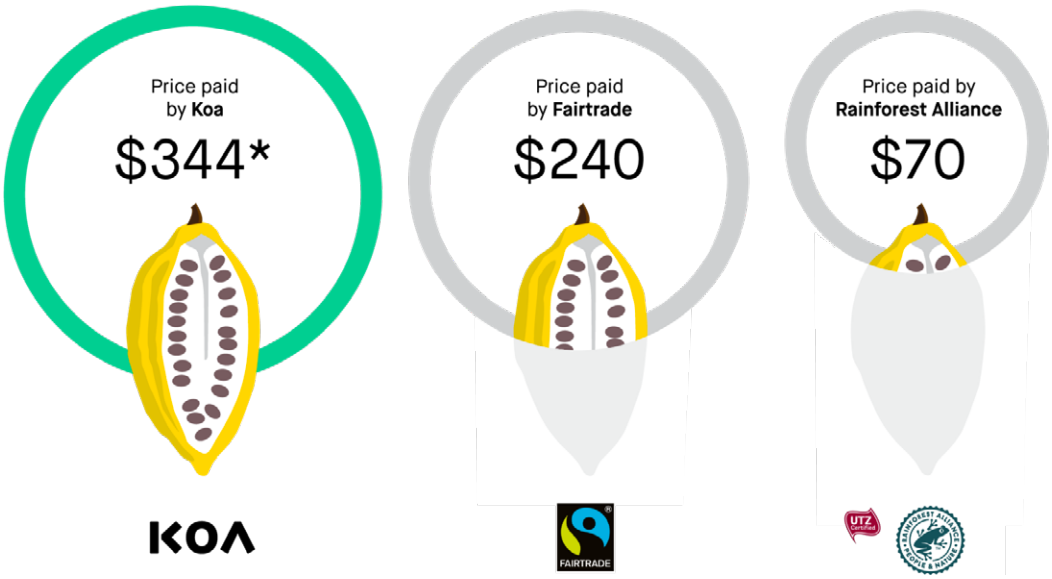
The output is then processed by a factory located in Assin Akrofuom, a town on the Gyimi River in the Ashanti region of Ghana, so that the products can be pasteurized, packaged and ready for shipment. The Koa platform required the involvement of three partners, SeedTrace, MTN and Topl.

Seedtrace, founded in Berlin in 2019 operates a blockchain dedicated to logistics traceability. Ana Selina Haberbosch, CEO of Seedtrace explains that she wants to "*set new standards in this way to ensure that information is verified, cannot be manipulated and is accessible in real time for all stakeholders*."

MTN, meanwhile, is Africa's largest mobile network operator, with 272 million customers in 19 markets in Africa and the Middle East. Kao uses MTN Mobile Money, "*a secure electronic service that allows MTN Mobile Money wallet holders to store funds, send and receive money, make payments and a number of other transactions simply by using their cell phone*[46]". This is the mobile service used to pay small producers.

Finally, **Topl** is an "*impact technology* company *that builds a blockchain solution to enable organizations and individuals to prove their ethical and sustainable practices*[47]".

46 "MTN Ghana", MTN, retrieved May 11 2022, https://mtn.com.gh/
47 "TOPL", Github, retrieved May 11 2022, https://github.com/Topl



Koa Impact. Source: Koa, https://koa-impact.com/radical-transparency/

Topl's blockchain, created in 2018, is a permissionless public blockchain[48], based on a *proof-of-stake** consensus mechanism derived from Ouroboros of the Cardano public blockchain.

The interest of using a blockchain allows to offer another form of transparency than labels like the "Fairtrade" system or "Rainforest Alliance and UTZ", while ensuring a more important income for the small producer. Indeed, the Fairtrade system, for example, allows "*the consumer to identify products whose ingredients are from fair trade and whose production, processing and marketing meet Fairtrade standards, responding to a precise specification*[49]".

To ensure compliance with these specifications, Fairtrade calls on an independent certification body, FLOCERT, which mobilizes nearly 100 auditors based in five offices on four continents to conduct audits of Fairtrade-labeled producer organizations at least twice in each three-year cycle, as well as, occasionally, during unannounced audits[50] .

Koa prides itself on offering a much higher price than the "Fairtrade" or "Rainforest Alliance" and UTZ labels, which only buy cocoa beans from small producers (Source image: https://koa-impact.com/radical-transparency/), but also on ensuring real-time transparency of payments made to small producers.

48 "Virtual reality adapting coffee supply chains to covid-19", Topl, retrieved June 14 2022, https://uploads-ssl.webflow.com/60f98f46d44e675abb7e66ea/611c66dff0c7e5f1ea9f7710_60776766cd67dd8cfd4206c5_Final%20Whitepaper%20(1).pdf

49 "Fair Trade: Frequently Asked Questions (FAQ)", Fairtrade, retrieved May 11 2022, https://www.fairtrade.net/about/faq

50 "Controls in practice", Fair Trade/ Max Havelar, retrieved May 11 2022, -https://maxhavelaarfrance.org/le-commerce-equitable/certification-et-controle

Mobile payments are verified and stored on a blockchain, becoming publicly available. "*Instead of a person entering information on the blockchain, it links the mobile money transaction data,*[51]" says Francis Appiagyei-Poku, Koa's director of finance and administration. "*This combination allows us to verify additional income for farmers, provide full proof and increase trust among stakeholders*.[52]"

Textile

According to WWF, "*cotton is the most widely grown profitable non-food crop in the world. Its production provides income to more than 250 million people worldwide and employs nearly 7% of the workforce in developing countries. About half of all textiles are made from cotton.*[53]"

The textile and clothing manufacturing industry is one of the most complex sectors, especially because it involves a cascade of subcontractors that cover the entire manufacturing cycle, from the harvesting of raw materials to the elaboration of final products, which, for some, "*makes traceability almost impossible*[54]".

Nevertheless, many companies have carried out on supply chain traceability for the textile and apparel industries by deploying applications or platforms based on private or public blockchains.

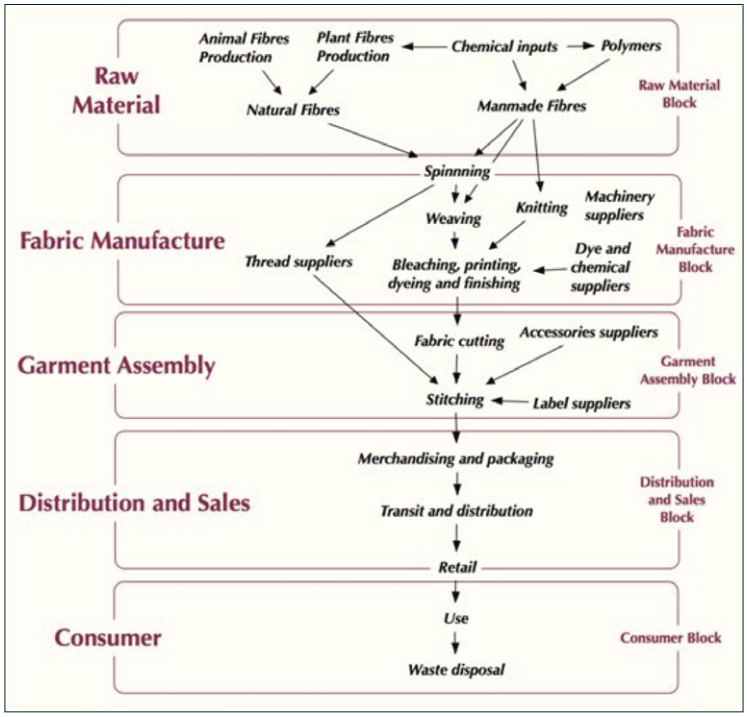
Among the operators that have implemented a private blockchain, **Retraced GmbH** in Germany has been offering "*a sustainable supply chain management software solution that enables fashion brands to coordinate their supply chains and achieve their sustainability goals*" since 2019.

The platform leverages a blockchain built on Oracle Autonomous Database, a cloud service offered by Oracle as well as Oracle Blockchain Platform, based on Hyperledger Fabric.

As a result, it's an enhanced ERP software that allows brands to embark on supply chain management. The company boasts of tracking 2,500 supply chains, 2,000 suppliers representing 2 million products.

Genuine Way founded in 2018 in Switzerland, **Nyala** created in 2019 in Belgium, **the UK Fashion and Textile Association** (UKFT) in partnership with IBM, the **U.S. Cotton Trust Protocol** relying on **TextileGenesis™** or **Verofax**, based in the United Arab Emirates since 2018 are some of these many startups

51 "Koa and seedtrace take transparency to the next level, using blockchain", Seedtrace, retrieved May 11 2022, https://seedtrace.org/case-study-with-koa
52l *Ibid.*
53"Cotton", WWF Sustainable Agriculture, retrieved May 11 2022, https://www.worldwildlife.org/industries/cotton
54 Bullón Pérez, Juan J., Araceli Queiruga-Dios, Víctor Gayoso Martínez, and Ángel Martín del Rey. 2020. "Traceability of Ready-to-Wear Clothing through Blockchain Technology" *Sustainability* 12, no. 18: 7491. https://doi.org/10.3390/su12187491



Ready-to-wear Clothing Supply Chain

Source: Bullón Pérez, Juan J., Araceli Queiruga-Dios, Víctor Gayoso Martínez, and Ángel Martín del Rey. 2020. " Traceability of Ready-to-Wear Clothing through Blockchain Technology " *Sustainability* 12, no. 18: 7491. https://doi.org/10.3390/su12187491

or consortium that have launched or are customers of a "*blockchain as a service*" offer, based on the model of a "Cloud offer" that allows a brand to use a centralized platform to track suppliers on a more or less complex supply chain.

Other initiatives rely on a public blockchain, such as **Devery.io**, which has developed a decentralized verification platform whose principle is to be able to "tag" and "track" any product or material on the Ethereum public blockchain.

According to Devery.io's white paper, the protocol uses a token called the Entry Verification Engine[55] (EVE) and allows "*manufacturers, brands, retailers and any other party to assign unique signatures to any product, service or digital asset sold, issued and exchanged online. The unique signatures are stored on the Ethereum network and can be queried to determine contextual data (including location, date, manufacturer/point of origin, and verification party identification).*"

55 "Devery (EVE)", CoinMarketCap, retrieved May 11 2022, https://coinmarketcap.com/fr/currencies/devery/

The goal of Devery.io is to create an ecosystem of verification applications that communicate and interact with each other through the Devery protocol and the EVE token.

The protocol, open source[56] , allows developers to create verification applications using pre-developed smart contracts to simplify the integration of services with enterprise customers, while relying on an Ethereum-based public blockchain.

56 “Devery”, Github, retrieved May 11 2022, https://github.com/devery

ISSUES AND QUESTIONS

The promise of blockchain initiatives in the area of supply chain traceability would be to serve as a tamper-proof registry that allows for the meticulous tracking of information provided by a multitude of different actors interacting on a supply chain.

The first question to ask when faced with this type of initiative is how the first memberof the supply chain is included. Indeed, the implementation of a blockchain for traceability purposes requires at *least* an internet connection, which is far from being the case in remote areas.

There is also the question of who verifies the information provided by these actors. Once data is recorded on the ledger, who guarantees the trustworthiness of the information transmitted especially with Internet of Things (IoT) components ? For some supply chain players deploying a blockchain to maintain the integrity of data in a shared ledger, the most important thing is not the data but the person responsible for it.

A French company, **Ownest**, has been working for several years to implement supply chain traceability systems based on non-fungible tokens (NFT*) attached to products, goods and objects.

The objective is to ensure traceability with the people in charge of them as they interact in the supply chain. For Quentin de Beauchesne, co-founder of Ownest, "*the NFT* is one of the best representatives of this transfer of value via a blockchain, and the traceability it provides makes it possible to track who owns it at a given time. If we add the ability to accept or refuse this NFT*, then it can carry the responsibility on a real or virtual property*[1]".

The fact remains that international supply chains involve more and more intermediaries, making the origin of raw materials and the way they are extracted or harvested increasingly opaque.

1 "NFTs in logistics?", Quentin de Beauchesne, May 18, 2021, https://ownest.io/news/nft-month-nfts-logistique

Social and environmental externalities, linked to human rights violations and environmental degradation, are rarely reflected in the selling price, which is often the only arbitration criterion for buyers.

How can we investigate the social and environmental dimensions of the production and creation of products and goods, and in particular the working conditions of the first links in the chain?

Moreover, there are industrial sectors where, with or without blockchain, the opacity of practices depends on the geopolitical context of the countries where the raw materials are extracted or harvested, and on the way in which they are then sold on the financial markets.

In the *commodities* market, the only criterion is often the buying and selling price. As one supply chain professional said in an interview for the report *From Blockchain to Sustainability in Supply Chains*[2] *"right now, if you buy a conflict-affected material, like tin, on the global market, you see tin at one price, tin at another price [...] and you don't know the difference. Was it mined from the bottom of the sea by destroying the seabed? Was it extracted from a responsible mine? Was it mined using forced labor? You don't know. And these companies can produce reports, but there are all kinds of problems. How can you know without visiting? And so if you visit, how many audits have to be done and so the more sustainability measures a company takes, the more audits they go through, the more people visit the mine, the more work they have to do, and it costs more. As a result, prices are higher in the raw materials market. If you buy a raw material, it's really the price that makes the difference. They are at a disadvantage. If you implement a tracking and tracing solution, it costs money. Who pays for it? The miners, the ones you're trying to help, and someone comes along and says I'm giving you a 30% laundering bonus for selling illegally to my army. Suddenly, you're discouraging people from acting responsibly*[3]".

2 "Supporting Information - Unfinished Paths-From Blockchain to Sustainability in Supply Chains", Susanne Köhler, Massimo Pizzol and Joseph Sarkis, Frontier in Blockchain, 2021, doi: 10.3389/fbloc.2021.720347
3 *Ibid.*

Thus, blockchains are not a one-fit-all solution. A major problem of supply chains, which goes hand in hand with the increasing complexity of supply chains, concerns the fragmentation of information held by each of the actors that make it up.

This problem is also found in the mining industry and in the textile industry, which is responsible for 17 to 20% of global water pollution according to the World Bank[4] .

The challenges of supply chain traceability are intrinsically linked to the multitude of players interacting with each other without knowing each other within complex and often opaque supply chains.

What should we think of the multiplication of blockchain initiatives, often private, whose interest seems limited to those who deploy them?

The initiatives consisting in deploying a private blockchain allow a small number of actors to ensure the centralized governance of the service.

According to TE-FOOD "*large food companies like WalMart, Carrefour or Nestle can be convinced to implement private blockchain solutions like IBM Food Trust. In reality, centralized blockchains - where all nodes are provided by the solution provider - are no more credible than a centralized database*[5]".

The centralized and proprietary nature of these initiatives is a replica of traditional systems, even if they are more efficient because they are managed by one entity or a small group of companies.

Another way to federate all the players in a sector would be to share a common language, a common repository, a common register that would belong to everyone and to no one, like Internet standards, and whose governance would no longer depend on a single player or a group of players who coordinate themselves by taking advantage of the asymmetry of information they enjoy.

4"The environmental impact of fashion and fast-fashion," Valentine Ambert, Youmatter, February 16, 2021, https://youmatter.world/fr/impact-environnemental-mode-fast-fashion-textile-pollution-environnement/

5 "8 Food Traceability Predictions for 2020," TE-Food, retrieved May 11, 2022, https://te-food.com/8-food-traceability-predictions-for-2020/

Several professionals working in the field of traceability and logistics explained to us that currently, the technical dimension of these blockchain projects was not so much the biggest challenge as the one of governance. Indeed, a blockchain project makes sense in an environment where trust is lacking and where governance is decentralized.

AGRICULTURE & FOOD

AGRICULTURE AND FOOD

by **Lucas Zaehringer**, co-founder of Positiveblockchain.io and *Lead Europe* at Verity Tracking.

Number of projects in the directory: 98

Number of active projects: 56

Name of active projects: Agri10x ; Agrichain ; Agridigital ; Agriledger ; agri-wallet ; Agroplug ; Agrotoken ; agrotrust ; AgUnity ; AXIchain ; Bananacoin ; Bart.Digital ; BeefLedger ; Bext360 ; Bitcliq - Lota Digital ; Bitcow ; Bloombloc ; Cardano / Ethiopia ; Cerealia ; Chainvine ; Choco4Peace ; Connecting Food ; Covantis ; eAgronom ; FairChain Foundation ; Fairfood ; Farmer Connect ; Fishcoin ; Food Trax ; Foodchain ; FoodGates ; Foodlogiq ; Foodtrack ; Fransine Farm Norway ; Gavea ; GrainChain ; Hara ; IBISA ; IBM Food Trust™ ; Mixing Bowl ; Omnichain ; OpenSC (WWF) & Nestlé ; Rice Exchange ; Ripe ; SmartAgro ; SPROUT ; TagONE ; TE-FOOD ; The new fork ; Trace My Egg ; TraSeable Solutions ; TurboCereal ; Twiga Foods ; VeriTag ; Verity Tracking ; Verstegen and Fairfood Nutmeg ; Wholechain ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

Context and issues

Food and Agriculture Organisation of the United Nations (FAO) and the achievement of the Sustainable Development Goals

The agriculture sector employs globally more than 1.3 billion people or about 40% of the world's workforce[1], while being the main source of income for 80% of the world's population who live on less than $3.10 a day[2].

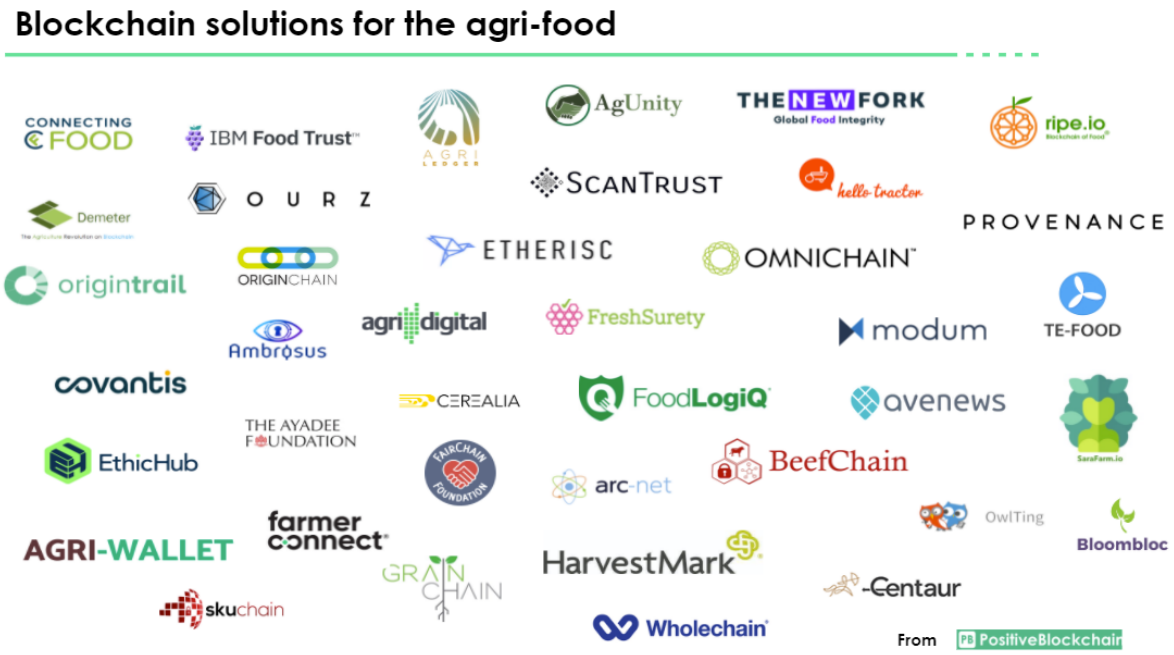
The development of the agricultural sector is one of the main pillars that would make it possible to feed the 9 billion people that will be living on the planet in 2050[3].

What is the contribution, still modest, of DLTs (Distributed Ledger Technologies) in this field?

1 "With nearly 40% of the world's workforce, agriculture is the leading provider of jobs on the planet," Momagri, Terre-Net, September 1, 2012, https://www.terre-net.fr/actualite-agricole/economie-social/article/avec-pres-de-40-de-la-population-active-mondiale-l-agriculture-est-le-premier-pourvoyeur-d-emplois-202-78960.html

2 "Agriculture and Food", World Bank, Oct 4 2021, https://www.banquemondiale.org/fr/topic/agriculture/overview

3 "World Population Prospects. Key Findings and Advance Tables," United Nations, 2015, https://population.un.org/wpp/publications/files/key_findings_wpp_2015.pdf



Selected blockchain players in the agri-food sector, Source: Positiveblockchain.io

In particular, in the areas of food product traceability, insurance and financing, or in the orchestration of agricultural market mechanisms which blockchain can help make supposedly fairer and more transparent? Here is an overview of the initiatives at work in this field.

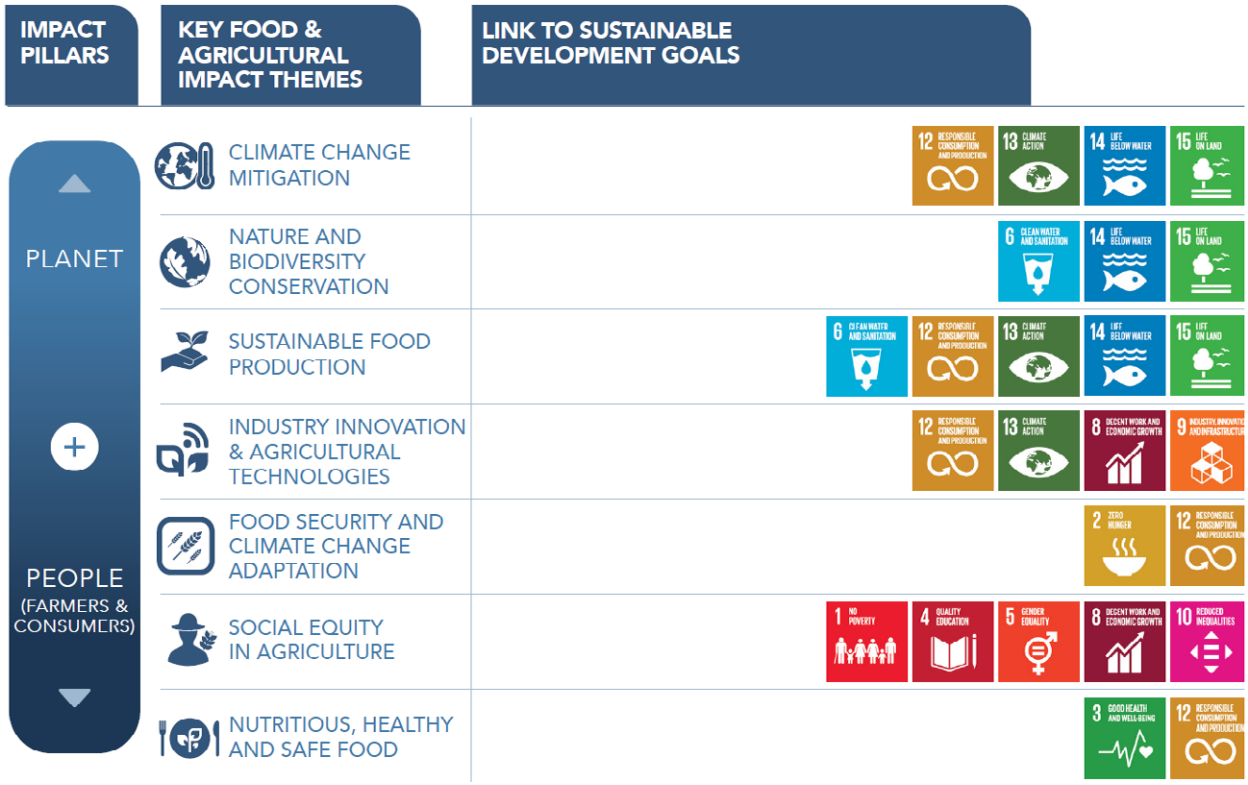
A sector that is currently far from achieving the Sustainable Development Goals

We analyze here the activities of agriculture, forestry, fisheries and industries directly related to food, which is the scope of the Food and Agriculture Organization of the United Nations (FAO)[4].

The latter reports a concerning reality in 2021 regarding the achievement of the Sustainable Development Goals for 2030, which set a number of targets in terms of nutrition, eradication of hunger and poverty, climate change related to farms or the search for efficiency of food systems including waste. The relationships between the Sustainable Development Goals and agriculture and food are presented in the table below:

For example, according to a recent FAO report, "*in 2020, the COVID-19 pandemic propelled world hunger in 2020, which increased from 8.4 to as much as 10.4 percent of the global population… moderate to severe food insecurity increased between 2015 and 2019 and now affects 25.9 percent of the world's population*[5] ", an increase that has been

4 "About FAO", FAO, retrieved May 19 2022, https://www.fao.org/about/en/
5 "Monitoring progress of the food and agriculture-related SDG indicators 2021," FAO, 2021, https://www.fao.



Source : Valoral Advisors, November 2018 ; "*Impact investing in the global food and agricultural investment space*", Lucía Garzarón, Roberto Vitón, Valoral Advisors, November 2018, https://www.valoral.com/wp-content/uploads/Valoral-Advisors-Impact-Investing-November-2018.pdf

observed for many years, but which "*in 2020 was equal to that of the previous five years combined*[6] *"*. Furthermore, the FAO reports "*systematic disparities* [...] *in the incomes and productivity of small-scale and large-scale food producers*[7] *"*.

The FAO highlights other major problems related to water stress, reduction of forest area, high price volatility, inequality of remuneration or land rights between men and women, use of chemicals or pesticides,endangerment of biodiversity or persistence of illegal fishing.

Blockchain, agri-food and the European Union

In developed countries, agriculture now accounts for only 4.2% of direct employment. Government policies focus mainly on providing transparency for the consumer, pricing mechanisms or simplifying the numerous regulations that complicate the work of farmers[8].

In the European Union, various initiatives and reforms impact the future of agriculture and food systems.

org/sdg-progress-report/2021/fr/
6 *Ibid*.
7 *Ibid*.
8 "French agriculture, one of the most regulated in the world", Médiaterre, accessed on 21/06/2022, https://www.mediaterre.org/actu,20210910090956,2.html

The new Common Agricultural Policy (CAP) that will be implemented over the period 2023-2027 is intended to be "*fairer, greener and more* performance-*based*"[9]. Cluster 6 "Food, Bioeconomy, Natural Resources, Agriculture and Environment" of the Horizon Europe program [10][11] includes projects related to biodiversity, forest and farmland management, food systems, or the environmental impact of agriculture.

The new European green pact[12] ("*Green Deal"),* which aims to make Europe climate neutral by 2050, also presents strategic axes and investment programs - up to 1 trillion euros for the next ten years[13] - related to this sector. In particular, one of the components of the Green Pact is the "Farm2Fork" strategy[14] which aims to create "*a fair, healthy and environmentally friendly food system*[15] ".

The themes put forward that will be the subject of new legislation concerning the protection of biodiversity, the role of agriculture in reducing CO^2 emissions, but also the development of organic farming (8.5% to 25% of farmed land by 2030), the development of the circular economy, the reduction of pesticides (50% by 2030) or animal welfare.

The European Union recently launched a call for tenders to define its blockchain roadmap for the agri-food sector[16]. Numerous applications of the technology are mentioned: better traceability and eco-responsibility in the food supply chain, transparency for consumers, the search for a balance of power between actors in the system, the implementation of labels or mechanisms to preserve biodiversity, and the optimization of administrative processes.

9 "Common Agricultural Policy 2023-2027", European Council, accessed June 21, 2022, https://www.consilium.europa.eu/fr/policies/cap-future-2020-common-agricultural-policy-2023-2027/
10 Horizon Europe is the European Union's "framework program" for research and innovation that succeeds the Horizon 2020 program as of January 1er, 2021.
11 "Horizon Europe: making sure EU investment in innovation and research has an impact," European Commission, retrieved Jul 21 2022, https://www.consilium.europa.eu/fr/policies/horizon-europe/#:~:text=The%20European%20Commission%20has%20proposed,additional%20euros%20from%20the%20InvestEU%20Fund
12 A Green Deal for Europe, European Commission, retrieved Jul 21 2022, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_fr
13 "The European Green Deal Investment Plan and Just Transition Mechanism explained," European Commission, retrieved Jun 21 2022, https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24,
14 "From farm to table: how the EU wants to green our plates", Valentin Ledroit, Toute l'Europe.eu, 27 October 2021, https://www.touteleurope.eu/agriculture-et-peche/de-la-ferme-a-la-table-comment-l-ue-veut-verdir-nos-assiettes/
15 *Ibid*
16 "Research & innovation roadmap for blockchain technologies in the agri-food sector", European Commission, retrieved May 19 2022, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2021-farm2fork-01-07

Blockchain and traceability in the food system

Blockchains and food safety control

The food control standards and systems put in place by governments aim to ensure that the products available are "*safe, of good quality and fit for human consumption, comply with food safety and quality standards and are labelled honestly, accurately and in accordance with the law*[17] ". The World Health Organization (WHO) reports[18] that food safety issues are responsible for more than 200 diseases worldwide. Food contamination affects 600 million people, or one in ten, and kills 420,000 people annually. Lost productivity and medical expenses related to this scourge in low-income countries are estimated at $110 billion.

We remember the mad cow crisis in France in the 1990s[19], the scandal of beef or lamb substituted by horse meat that broke out in the European Union in 2013[20], the scandal of adulterated infant milk in China[21], the salmonella epidemic in papayas sold in the United States in 2017[22], the listeriosis crisis in Polony sausages marketed by Tiger Brands that would have caused the death of 216 people in South Africa[23], and finally, very recently, the cases of contamination due to E.coli bacteria in Buitoni pizza dough[24].

In a country like Singapore, for example, where 90% of food products are imported, food safety is a major issue. In the period from April to December 2019, the Singapore Food Agency (SFA) reported that 13% of imported fruits and vegetables did not pass the quality tests in place due to the amount of chemicals or pesticides detected[25].

17 "Food Control System", FAO, retrieved May 19 2022, https://www.fao.org/food-safety/food-control-systems/fr/
18 "Food Safety", WHO, retrieved May 19 2022, https://www.who.int/news-room/fact-sheets/detail/food-safety
19 "February 28, 1991, first case of mad cow disease in France", Ina.fr, November 6, 2007 - Updated February 24, 2021 https://www.ina.fr/ina-eclaire-actu/28-fevrier-1991-premier-cas-de-vache-folle-en-france
20 2013, the scandal of horse meat in lasagna breaks, Ina.fr, Apr. 16, 2019, https://www.ina.fr/ina-eclaire-actu/2013-le-scandale-de-la-viande-de-cheval-dans-les-lasagnes-eclate
21 "Adulterated milk: the health disaster spreads in China", Le Monde with AFP, September 16, 2008, https://www.lemonde.fr/asie-pacifique/article/2008/09/16/le-scandale-du-lait-frelate-prend-de-l-ampleur-en-chine_1095986_3216.html
22 "Deadly salmonella outbreak linked to papayas" Debra Goldschmidt, CNN, July 21, 2017, https://edition.cnn.com/2017/07/21/health/papaya-salmonella-outbreak/index.html
23 "Listeriosis outbreak triggers panic in southern Africa" Jean-Philippe Rémy, Le Monde, March 6, 2018, https://www.lemonde.fr/afrique/article/2018/03/06/l-epidemie-de-listeriose-declenche-un-vent-de-panique-en-afrique-du-sud_5266570_3212.html
24"Bacteria " E. coli " in Buitoni pizzas : a judicial information opened", Le Monde with AFP, May 12, 2022, https://www.lemonde.fr/societe/article/2022/05/12/bacterie-e-coli-dans-des-pizzas-buitoni-une-nouvelle-information-judiciaire-ouverte_6125876_3224.html
25 "Singapore is betting blockchain can cure its food safety crisis", Connor Sephton, ModernConsensus, Aug 27 2020, https://modernconsensus.com/technology/singapore-is-betting-blockchain-can-cure-its-food-safety-crisis/

This is an issue that can be observed throughout the Southeast Asian region and in many other regions around the world and that affects all actors in the value chain: consumers directly impacted by product quality defects; producers and importers who may suffer losses and fines; brands and distributors who also bear the risk of return and loss of entire batches as well as damage to their reputation.

The Singapore Food Agency (SFA) thus launched a solution in 2020 with **VeriTAG**'s platform, based on the public blockchain NULS[26]. Two main features are offered: VeriHub, focused on food exports and VeriShop, which works as a blockchain-based "loyalty app". Users/consumers are incentivized to scan their product as each time they verify provenance *via* the QR Code on the label, they will receive NULS tokens which can then be converted into Singaporean currency.

What is food traceability?

According to the Codex Alimentaris "*traceability is the ability to track the movement of a food through specific stages of production, processing and distribution*[27]. Depending on the national or regional regulations in place,data must be stored and transmitted to the different entities of the chain until the final sale. For this purpose, stakeholders involved use different IT systems based on barcodes and QR codes. Other information, in particular from Time Temperature Integrators (TTI), allows to ensure the state of freshness and conservation of products to avoid the development of pathogens.

Food safety assurance is managed by governments, international organizations such as the World Trade Organization (WTO), industry associations such as the Global Food Safety Initiative (GFSI) or the British Retail Consortium Global Standard (BRCGS), standardization bodies such as the International Featured Standards (IFS), the Global Standards 1 (GS1) coding standard or the International Barcode Network (IBN), to name a few.

In the case of the European Union, directives have gradually been put in place and are generally specified and completed by national laws: EEC HYGIENE 93/43, EEC TRACABILITY 178/2002 - article 18 of the General Food Law, EEC regulation 852/2004.

26 "Reach new heights with Nuls", Nuls, retrieved Jul 21 2022, https://nuls.io/
27 "Codex Alimentarius", FAO, retrieved Jul 21 2022, https://www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/fr/

In the United States, most devices are set up and monitored by the Food and Drug Agency (FDA). There are also ISO standards worldwide on food safety, including ISO 22000, 22002, 22004, 22005.

With all of these standards, operators in the food chain must at all times be able to provide information on the origin of the products used and the companies from which they sell their products. A number of procedures and systems must be put in place for this purpose.

*"I try not to use the words "*food chain*" but rather "*food system*," because we know that when you do these tracebacks, they're not direct,"* explains Frank Yannas, then head of food safety at Walmart in 2018[28].

As this quote illustrates, the problem is about integrating all inputs[29] into the food system starting with seeds. This presents a real challenge.

In the case of cattle for example, their department, identification number, date and place of birth, entries and exits (sales, slaughterhouse, etc.) are recorded and stored right in the ear of each animal, in a plastic loop equipped with a Radio Frequency Identification (RFID) tag.

But what do we know about the way they were fed, and the quantities, or not, of Genetically Modified Organisms (GMO) ingested?

Regulations are gradually evolving to integrate these issues, partly under the influence of consumers and associations.

The control authorities also follow the evolution of technologies allowing an easier, reliable and transparent traceability of food products.

The Food and Drug Administration (FDA) published on December 9, 2021 a new plan entitled the "*New Era of Intellignt Food Safety*[30] " based on four pillars, one of which is traceability aided by technology.

28 "From 7 days to 2 seconds: Blockchain can help speed trace-back, improve food safety & reduce waste", Elizabeth Crawford, Food Navigator - USA, Nov 6 2018, https://www.foodnavigator-usa.com/Article/2018/11/06/From-7-days-to-2-seconds-Blockchain-can-help-speed-trace-back-improve-food-safety-reduce-waste

29 In agriculture, we call "inputs" the different products brought to the land and to the crops, which do not come from the farm or from its proximity. Inputs are not naturally present in the soil, they are added to improve crop yields. Source : https://www.agriculture-nouvelle.fr/qu-est-ce-qu-un-intrant/

30 "The FDA New Era of Smarter Food Safety Low- or No-Cost Tech-Enabled Traceability Challenge", FDA, Precision FDA, retrieved May 19 2022, https://precision.fda.gov/challenges/13/results;%20accessed%2012-01-2021

The four elements of the U.S. Food and Drug Administration (FDA) plan[31]

In the "*FDA New Era of Smarter Food Safety Low- or No-Cost Tech-Enabled Traceability Challenge*" innovation competition[32], many of the 90 entries proposed to integrate blockchain-based technologies. Among the twelve winners, some propose traceability solutions based on blockchain, such as **TagOne**[33] or **Wholechain**[34] which has Mastercard as a partner.

For its part, GS1, the global organization in charge of standardizing coding methods used in the supply chain and which develops the Global Trade Item Number (GTIN), Global Location Number (GLN) and Electronic Product Code Information Services (EPCIS) standards, is also working with numerous blockchain traceability platforms to ensure integration with tracking systems and ERP software, traditionally used in the agri-food sector[35].

GS1 barcodes are scanned more than six billion times a day worldwide.

31 U.S. Food and Drug Administration: https://www.fda.gov/food/new-era-smarter-food-safety
32 "The FDA New Era of Smarter Food Safety Low- or No-Cost Tech-Enabled Traceability Challenge," FDA, Precision FDA, retrieved May 19 2022, https://precision.fda.gov/challenges/13/results;%20accessed%2012-01-2021
33 "TagOne is a groundbreaking Traceability Management System delivering radical transparency to the food and natural products supply chain, from seed to sale.", Tagone, retrieved May 19 2022, https://www.tagone.com/
34 "Wholechain - FDA New Era of Smarter Food Safety Low Cost / No Cost Traceability Challenge Video", Envisibile, YouTube, retrieved May 19 2022, https://www.youtube.com/watch?app=desktop&v=291VY5VGewY
35 "The Role of GS1 in blockchain based food traceability", TE-FOOD, Medium, May 25 2018, https://medium.com/te-food/the-role-of-gs1-in-food-traceability-857c1a1d1642

IBM Food Trust

Food safety issues are at the origin of the innovations that gave birth to the IBM Food Trust. In 2015, new laws in China, notably the Safety Food Law[36], tightened controls on the production, processing and transportation of food products. At the same time, players like Walmart were plagued by food safety issues.

The latter launched the *Walmart Food Safety Collaboration Center* in Beijing in 2016. It also launched two test projects in 2017 with IBM's blockchain technology, Hyperledger Fabric and the support of China's Tsinghua University. One on pork in China, the other on mangoes from South America. The objective then, which is still the same today, was to integrate points in the product's supply chain *via* the IBM blockchain technologies in order to be able to trace its exact origin in record time: 2.2 seconds announced in the case of mangoes traced *via* the blockchain, compared to 7 days previously.

A "*complete traceability from A to Z*" according to IBM, which saves considerable time for the activities of retailers in the context of a health crisis, but also saves money since the batches to be withdrawn from the market can be targeted very precisely and the problem of origin more quickly resolved.

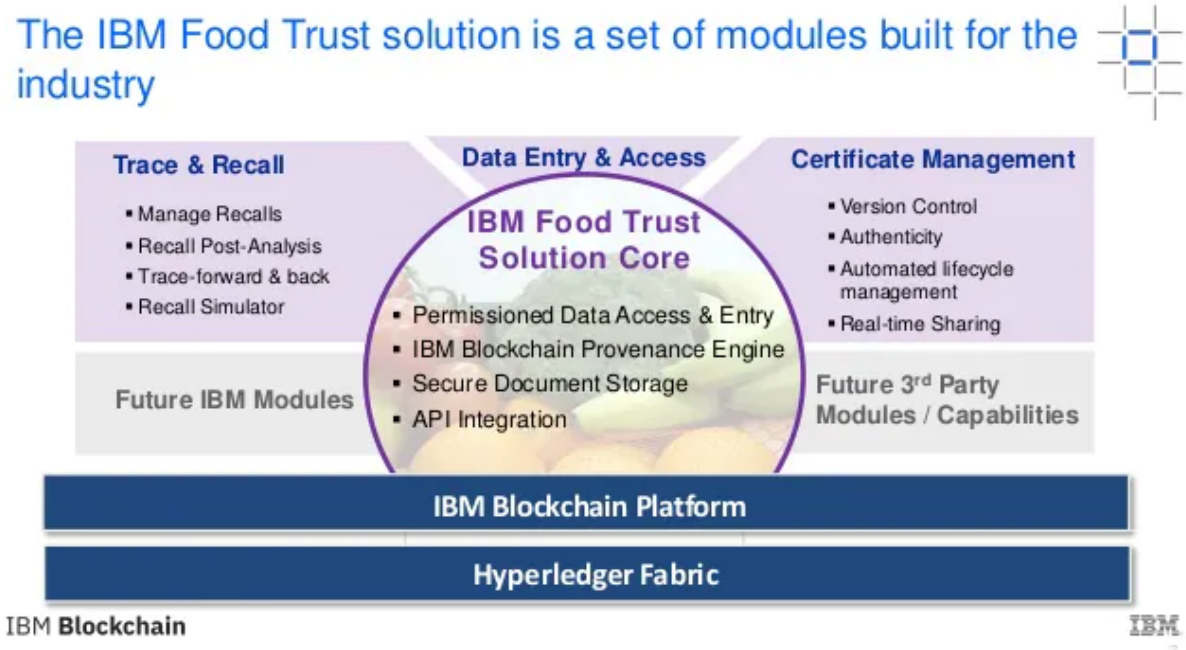
In the event of a health crisis, entire product lines are typically destroyed and crisis communication deteriorates consumer confidence in the product and brand.

In December 2017, IBM launched the *Blockchain Food Safety Alliance*[37] with several partners including Walmart, Tsinghua University in China and Chinese e-commerce giant JD.com, with the goal of standardizing a traceability method with IBM's blockchain platform. Building on this promising start, which was widely reported, IBM founded the "IBM Food Trust" for the U.S. and European markets.

Today, IBM Food Trust is a solution presented as mature and adapted to different types and sizes of players in the food system.

The solution offers different modules related to traceability and counts among its customers Walmart (more than 25 products including mangoes, salads, strawberries), the *Norwegian Seafood Trust*[38] (Norwegian salmon), CHO (Tunisian olive oil), Carrefour (chicken, orange, milk, cheese among others), Albertsons (lettuce), Nestlé (coffee brands), Heifer (cocoa and coffee from Honduras), Tyson Foods (beef), Sustainable Shrimp Partnership (shrimp from Ecuador), Raw Seafoods (seafood),

36 "Food Safety Law of the People's Republic of China (2015)," HFP Law & Intellectual Property, 2016. https://www.hfgip.com/sites/default/files/law/food_safety_-_16.02.2016.pdf
37 "Blockchain in food safety", IBM Food Trust, retrieved Jul 21 2022, https://www.ibm.com/blogs/blockchain/category/blockchain-in-food-safety/
38 "Safe food - from fjord to table", Norwegian Sea Food Trust Alliance, retrieved Jul 2022, https://norwegianseafoodtrust.no/



IBM Food Trust. Source : IBM, https://www.ibm.com/fr-fr/blockchain/solutions/food-trust

Golden State Foods (fast food meat), SecQuAL (English pork) and many others.

Different user accounts define when suppliers can upload each type of data. Sometimes it may be a simple record of a logistics operator, such as the receipt of a load of olive oil in a warehouse. The information is shared *via* software with partner actors (distributors, intermediaries, supermarkets, etc.) and because the data is recorded in a blockchain, it cannot be altered or deleted.

Other information include audit data, identification numbers, supplier names, authorizations or certifications. Producers can, for example, use a smartphone to record origin information, GPS coordinates, time, and production data at the same time that this information is attached to a bag of coffee or a shrimp shipment coming off the ocean. End consumers can see the same information selected and presented in an end consumer application.

Example with Farmer Connect

The Farmer Connect solution was developed in Switzerland in 2019 using the IBM Food Trust platform. Consumers scan the barcode on the coffee package with the “Thank my farmer” app and then access the farmer’s story and the path of the coffee bag on an interactive map. Sustainable projects can also be supported directly through the app.

The idea is to create a link between the two ends of the coffee chain, from producer to consumer. *“The aim is humanizing each coffee drinker’s relationship with their daily cup. Consumers now can*

Application "*Thank my Farmer***"**,
Source : https://www.thankmyfarmer.com/

play an active role in sustainability governance by supporting coffee farmers in developing nations" explains David Behrends, founder and president of Farmer Connect.

The company closed a $9 million Series A round in 2021 and is deploying its solution with a number of coffee distributors including UCC Coffee (UK), Beyers Koffie, The Colombian Coffee Growers Federation (FNC), ITOCHU Corporation, Jacobs Douwe Egberts (JDE), The J.M. Smucker Company, Rabobank, RGC Coffee, Volcafe, Sucafina and Yara International.

<u>The central role of the consumer</u>

Blockchain traceability projects allow for greater vigilance and reaction capacity in the face of food safety issues. This certainly benefits upstream players in the food system, brands and distributors, but also the consumer, who must be put back at the center of the debate. *"In 2020, many consumers have become aware that our food system is absolutely essential, questioning both the supply of supermarket shelves and the environmental impact of food production. As we work towards economic recovery, building trust between consumers and the food sector will be absolutely necessary if we are to achieve better food for all,"* said Saskia Nuijten, Director of Communications and Public Engagement at EIT Food. According to a recent EIT Food study, "*only four out of ten consumers (40%) are confident that the food products they buy are generally authentic, rather than fake or artificial* (...)

and 55% consider food generally safe"[39]. A more recent TIS report[40] estimates that 91% of consumers want more transparency from food brands.

Example with Connecting Food

Connecting Food is a French startup launched in 2016 to try to solve the major problems of food transparency and product safety and consumer trust. Hyperledger technology was chosen to develop Connecting Food.

In addition to traceability solutions for all actors in the agri-food industry, an innovative point of the Connecting Food solution is the focus on the ability to audit product quality in real time with the LiveAudit® module. Indeed, food safety regulations require audits and controls, but these are only carried out on a small proportion of the products tested.

The real-time solution is a guarantee of safety and confidence for both brands, and for consumers, who access information by scanning a QR Code on the product label. After completing seven industry pilots in 2019, growing from four to 27 employees the following year, Connecting Food entered the U.S. market in 2021, and is now establishing itself as a strong player in the ecosystem. Connecting Food currently operates in seven countries around the world and works with numerous clients from agricultural cooperatives to industrial giants like Nestlé, Mondelez and General Mills.

Real-time labelling in the context of the war in Ukraine

A recent problem has arisen as a result of the major disruptions to the cereal supply chain caused by the war in Ukraine. Manufacturers of sunflower oil asked the government for a derogation to use substitute products (rapeseed oil, palm oil, etc.), without changing the labelling[41]. The industrial reality is taking over the consumer's need for transparency.

Transparency and efficiency of supply chains

Here we want to highlight another benefit, besides transparency, of blockchain-based traceability systems for food chains. The implementation of these systems can indeed reveal deficiencies in the logistics of the product. For example, the Walmart mango pilot has reduced transit times through customs, which *ultimately results in* fresher products and potentially less waste during transport.

39 "Two thirds of European consumers trust their farmers", Pour Nourrir Demain, January 20, 2021,

https://www.pour-nourrir-demain.fr/deux-tiers-des-consommateurs-europeens-ont-confiance-dans-leurs-agriculteurs

40 Kantar Protéines XTC and Gira study for SIAL 2020.

41 "Sunflower oil: the label must reflect in real time the reality of the ingredients and their origins", Yves Puget, LSA-conso, Apr 29 2022, https://www.lsa-conso.fr/huile-de-tournesol-l-etiquette-doit-refleter-en-temps-reel-la-realite-des-ingredients-et-leurs-origines.410141

The blockchain traceability ecosystem

When it comes to blockchains and traceability, IBM's experiments have been accompanied by an impressive amount of projects. Already in 2016, the company **Provenance** experimented with solutions for tracing Indonesian tuna *via* a blockchain[42], then in 2018 the participants of the Ethereal summit organized by **ConsenSys** could scan the QR code of their sushi tray traced on the Ethereum blockchain thanks to the company **Viant**[43].

The industry is evolving rapidly, showing that blockchains have proven themselves as innovative technologies for improving our food systems. The PositiveBlockchain database lists no less than 90 projects related to food traceability. While some solutions are generalist and offer highly scalable solutions, others focus on niche products and markets in order to adapt to specificities: cocoa, coffee, palm oil, lettuce, pork, seafood, beef, cereals, chocolate, tuna, bananas, coconuts, rice, wines and spirits, etc.

Below are some notable projects and news in the field of food traceability through blockchain:

- Walmart plans to require all lettuce and spinach suppliers in the U.S. to trace their products *via* a blockchain platform[44]
- ADM, Bunge Ltd, Cargill and Louis Dreyfus Companies deploy blockchain solution to standardize and digitize food logistics[45]
- Alibaba has developed its Food Trust framework and filed over 90 patents related to blockchain technology[46]
- Wipro has joined the *Blockchain in Transport Alliance*[47], an organization focused on transportation and logistics with applications in the food industry
- Starbucks develops blockchain-based traceability system and app with Microsoft[48]

42 "From shore to plate: Tracking tuna on the blockchain," Provenance, retrieved May 19 2022, https://www.provenance.org/tracking-tuna-on-the-blockchain

43 "Moral Food: A Fish's Trek From 'Bait to Plate' on the Ethereum Blockchain," Alyssa Hertig, Coindesk, May 13, 2018, https://www.coindesk.com/markets/2018/05/13/moral-food-a-fishs-trek-from-bait-to-plate-on-the-ethereum-blockchain/ (Viant is now called Treum)

44 "Walmart plans to track its salads using blockchain by 2019," Carine Kren, 25 September 2018, courscryptomonnaies.com, https://courscryptomonnaies.com/actualite/walmart-prevoit-de-suivre-ses-salades-en-utilisant-la-blockchain-dici-2019

45 "ADM, Bunge, Cargill and Louis Dreyfus form partnership," Holly Demaree-Saddler, Oct 25 2018, worldgrain.com, https://www.world-grain.com/articles/11148-adm-bunge-cargill-and-louis-dreyfus-form-partnership

46 "Alibaba tops blockchain patent list," Coinrivet, Sep 4 2018, https://coinrivet.com/fr/alibaba-tops-blockchain-patents-list/

47 "Wipro joins Bita to drive Blockchain adoption in the transportation industry," Wipro, Aug 30 2018, https://www.wipro.com/newsroom/press-releases/2018/wipro-joins-bita-to-drive-blockchain-adoption-in-the-transportation-industry/

48 "Starbucks' Blockchain Allows Traceability to 380,000 Coffee Farms!", Peter Vogel, Foley & Lardner L&P, May 10 2019, https://www.foley.com/en/insights/publications/2019/05/starbucks-blockchain-allows-traceability-farms

- UNDP Accelerator Lab India launches a pilot in the spice market in India with a blockchain traceability and trading application[49].

Many startups and companies are now offering logistics traceability solutions based on blockchain:

- **Ripe.io**, founded in San Francisco in 2017, the company announced in 2019 to develop a software solution based on R3's Corda Enterprise private blockchain on Microsoft Azure.

- **FoodLogiQ**, launched in the United States in 2006, has converted to traceability *via* blockchain.

- **TE-Food**, the startup with 6,000 customers offers its "TrustChain" blockchain to many players in the food industry such as Chipotle, Auchan, Whole Food, Conagra, Tyson Foods and operates mainly in emerging countries.

- **SkuChain**, founded in 2014 in California, USA, specializes in supply chain. It offers a blockchain platform, "*Enterprise Collaborative Commerce Cloud*" (EC3), to ensure the management of contracts, purchases, financial and information flows in the international trade of many industries including food and beverage.

- **Provenance,** a British startup is developing a food supply chain transparency solution on the public Ethereum blockchain but also in the beauty and fashion sectors.

- **VeChain**, a startup launched in China in 2015, and which develops its own blockchain technology, offers a SaaS solution[50] "ToolChain" for the traceability of luxury and collectible products but also for the food industry.

- **OriginTrail,** launched from Slovenia, is built on the Ethereum, xDAI and Polygon public blockchains and offers a data exchange protocol (the *OriginTrail Decentralized Knowledge Graph* or "DKG") applied to, among other things, food supply chains.

- Players such as **TraceLab,** supported by European funds, are testing the OriginTrail solution (see *above*) in the context of organic agriculture.

- **Ambrosus** has been developing a platform, called AMB-NET, since 2017 in Switzerland, also focused on traceability in the supply chain and particularly food, based on components linked

49 "Accelerating agri-tech to transform food systems," Swetha Kolluri, Krishnan S Raghavan, Rozita Singh, The Pioneer, Jan 10 2022, https://www.dailypioneer.com/2022/columnists/accelerating-agri-tech-to-transform-food-systems.html

50 *Software as a service*: software accessed from a web browser.

to the Internet of Things (IoT).

- **SAP**, the German business and maintenance software company has launched a specialized division, named *SAP Blockchain Business Services,* to offer its blockchain platform to food manufacturers and organizations. Most notably, it demonstrated its solution with **Bumble Bee Foods** starting in 2019 for the traceability of its Indonesian yellowfin tuna from ocean to plate.

The tokenization of agricultural assets

If the use of blockchain in the context of food traceability seems to be unanimous, there are other cases of application of the technology, notably through the tokenization* of agricultural assets. The tokenization of agricultural assets attempts to solve the problem of loss of income due to inflation for farmers, allowing them to be less dependent on fluctuations in the price of their currency to obtain inputs and agricultural equipment.

This is particularly the case in Argentina, where agricultural exports are the main source of foreign exchange. They represent 75% of Argentine exports and almost 10% of the Gross Domestic Product (GDP). In addition, Argentina is characterised by a very high instability of its currency, the peso.

A farmer selling his products in pesos can therefore see the value of his sale melt away in a few days[51]. Thus, issuing a token, collateralized on real commodities, allows the farmer to access a crypto-asset indexed to the price of these commodities, in order to continue to supply himself with inputs and materials, thus escaping a possible devaluation of his currency.

Projects are emerging to offer crypto-assets based on agricultural assets like soybeans. This is the case with the "cryptosoja" launched by the **Agrotoken** platform, or a recent partnership between **CoreLedger** (blockchain infrastructure services) and **Abakus** (*peer-to-peer* financial services). According to Martin Furst, CEO of Abakus "*agriculture-backed tokens can solve the volatility and liquidity problems inherent in cash and equity savings plans. The tokenization of agricultural assets brings greater freedom to farmers who can now sell physically backed assets based on their own needs*." The benefit of these tokens is therefore that they are not subject to the devaluation of national monetary currencies due to inflation.

Hive Online (see Chapter "Peer-to-Peer Money and Programmable Money") wishes to use the tokenization of agricultural assets produced within a community to establish equivalences between these commodities in order to exchange them. In concrete terms, if 1,000 cashew nuts and 100 bricks of milk are produced within a community, each nut and each brick will be registered in a blockchain and then tokenized. Thus, it will be possible to exchange 10 cashew nuts tokens to obtain one brick of milk.

As for Grassroot Economics (see Chapter "Peer-to-Peer Electronic Cash System and Programmable Money"), it uses the quantities of agricultural commodities produced in a given community as collateral for the issuance of electronic vouchers, called Community Inclusion

51 "Hard-Hit Argentinian Farmers May Get Boost From Trading Platform for Tokenized Produce", Sebastien Sinclair, Coindesk, Jan 28 2021, https://www.coindesk.com/tech/2021/01/28/hard-hit-argentinian-farmers-may-get-boost-from-trading-platform-for-tokenized-produce/

Currency (CIC). These CICs can only be used as a means of payment within that community. The different commodities are registered on a blockchain, so as to keep a shared and updated record of the quantities produced. Then, CICs are issued, corresponding to the quantity of commodities produced. Thus, no more CICs can be issued than there are equivalent commodities in the community.

These two projects, which are quite different in their operation, nevertheless share a common point. Agricultural production is no longer subordinated to the fluctuating prices of the world markets for raw materials and agricultural products, but it is the fluctuating prices that are subordinated to the agricultural resources produced within the community. These two projects suggest the emergence of a new economy, at the service of farmers, made possible by the use of blockchain.

Agriculture and environmental protection

According to the European Environment Bureau[52], the agricultural sector is responsible for 26% of global CO2 emissions caused by human activity.

The Common Agricultural Policy (CAP) managed by the European Commission already provides a number of incentive and funding programs for environmentally friendly practices through "eco-regimes" and "agri-environmental and climate measures" (AECM[53]).

There is also a European Union Emissions Trading Scheme (ETS), a regulation on land use, land-use change and forestry (LULUCF), and since 2021 a regulation called "Effort Sharing Regulation[54]", stemming from the European program "Fit-for-55[55]" to share the effort to reduce emissions between each Member State.

52 "Beyond net-zero emission in agriculture: Creating an enabling climate governance for agriculture", European Environmental Bureau, retrieved May 19 2022, https://eeb.org/library/beyond-net-zero-emission-in-agriculture/

53 "Agro-environmental and climate measures (MAEC) and organic farming aids", France, Ministry of Agriculture and Food Sovereignty, March 11, 2022, https://agriculture.gouv.fr/mesures-agro-environnementales-et-climatique-maec-et-aides-lagriculture-biologique

54 "Questions and Answers - The Effort Sharing Regulation and Land, Forestry and Agriculture Regulation", European Commission, July 14, 2021, https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3543

55 "Adjustment to Objective 55", Council of the European Union, https://www.consilium.europa.eu/fr/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

Mechanisms that are currently considered to be ineffective in achieving the Sustainable Development Goals in the area of climate[56].

There are many ways to reduce greenhouse gas emissions in agriculture, including carbon *farming*, biomass use, regenerative agriculture practices, promotion of forestry for the rational use of forest trees, use of more natural fertilizers, reduction of pesticides, effluents and other chemicals, and promotion of organic farming (see Chapter "Environment and Climate"). In order to promote these practices and achieve the CO2 reduction targets, more effective support and financing measures are needed.

The implementation of a carbon market for agriculture decided by the European Commission in 2020 follows this objective while allowing for an increase in agricultural income[57]. According to a study published by Mckinsey, the global demand for carbon credits should increase fifteen fold by 2030 and 100 fold by 2050[58]. Agricultural mitigation or sequestration projects can provide the source of carbon credit that the market needs, which in turn facilitates the financing of these same projects. And this would be a boon for the European Union, which in 2019 set the goal of carbon neutrality for 2050 in its Green Pact.

Nevertheless, the European mechanism is far from being in place. Open carbon markets are highly fragmented, opaque, complex and not very accessible for environmental projects.

Many actors are exploring the potential of blockchain to facilitate the issuance, traceability and trading systems of carbon credits, such as **KlimaDAO**, **Regen Ledger** or the **Cambridge Carbon for Credit Center**, which we discuss in the chapter "Environment and Climate", but also **IXO**, which we discuss in the chapter "Peer-to-peer electronic cash system and programmable money", working in the field of impact verification.

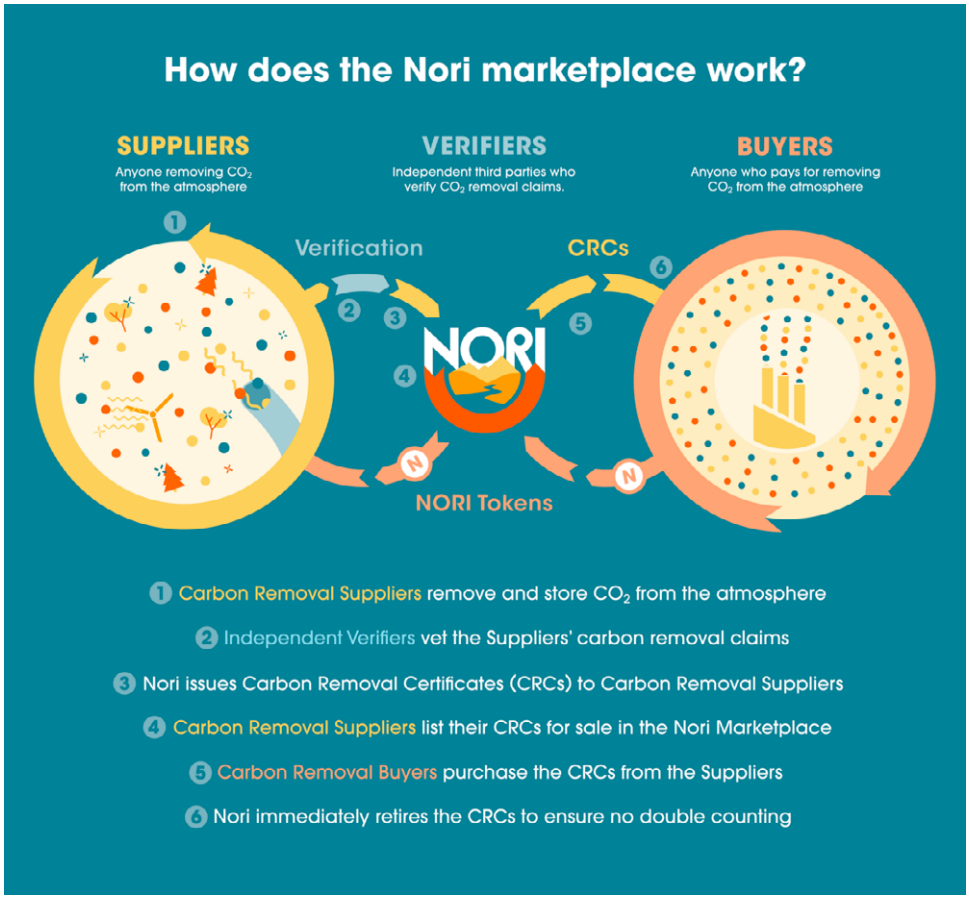
Note that a number of these projects are currently at work in the field of carbon traceability in relation to agriculture, such as **Nori**, **eAgronome** or **Verity Tracking**, which we present here.

Nori is a U.S. startup founded in 2017 to address the problem of agricultural carbon credits.

56 "European Union failed to reduce CO2 emissions in agriculture, says Court of Auditors", Belga, RTBF, 21 June 2021, https://www.rtbf.be/info/monde/europe/detail_l-union-europeenne-a-echoue-a-reduire-les-emissions-de-co2-dans-l-agriculture-selon-la-cour-des-comptes?id=10788603

57 "European Parliament gives green light to carbon credit scheme for agricultural sector," Cultiveille, Cultivar, Oct 14 2020, https://www.cultivar.fr/sinformer/le-parlement-europeen-donne-son-feu-vert-pour-un-regime-de-credits-carbone-pour-le-secteur

58 "A blueprint for scaling voluntary carbon markets to meet the climate challenge", Christopher Blaufelder, Cindy Levy, Peter Mannion, and Dickon Pinner, McKinsey Sustainability, Jan 29 2021, https://www.mckinsey.com/business-functions/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge



Source : Nori, https://medium.com/nori-carbon-removal

Nori's goal at the time was to design a system in which every dollar invested could be used to remove carbon from the atmosphere. Nori raised $7 million in Series A funding in 2022 and was working in February with ten farms whose farmers have received $1 million in revenue so far, with 2,200 carbon credit buyer transactions[59].

Nori manages two different assets, an NRT and the Nori Token. The NRT is a "*Nori Carbon Removal Tonne*" which represents one tonne of CO^2 removed from the atmosphere for at least ten years.

A supplier of NRTs can then register them on the Nori market. NRTs, in turn, are sold directly to individuals and organizations seeking to mitigate carbon emissions.

eAgronome is an Estonian *startup* that develops agricultural management and financing solutions. The company has a blockchain-based carbon program and raised €2.3 million in 2022 for its Solid World DAO* project based on a fork* of **OlympusDAO**. The DAO will use pre-certified agricultural carbon credits as a reserve in order to provide the necessary liquidity to environmental project holders in the agricultural field.

59 "Immune to irony, Nori puts a carbon market on the blockchain," Haje Jan Kamps, techcrunch.com, Feb 24 2022, https://techcrunch.com/2022/02/24/nori-series-a-carbon-blockchain/

Indeed, the certification of carbon projects, and therefore the guarantee of financing for this type of project, can sometimes take up to five years, which is an obstacle to the development of effective environmental solutions. Pre-certified credits will be issued as SCTs (Solid Carbon Ton), and other environmental co-benefits of projects will be issued as non-fungible tokens (NFTs ERC-721). Buyers and investors can therefore choose to invest both in carbon offsets and in the contribution to certain Sustainable Development Goals addressed by the project (biodiversity, inclusion, protection of natural resources, etc.).

Verity Tracking is another startup active in the agricultural sector. The joint venture is a collaboration between the German *startup* **Blocksize Capital** (digital asset *trading* infrastructure) and the **Colorado-based** listed company **Gevo**. The latter transforms agricultural raw materials and waste into chemicals and ethanol, notably for the production of biofuels in the aviation sector.

As the visual below illustrates, Gevo's goal is to maximize circular economy principles and sustainable practices in its value chain to minimize the carbon intensity of its biofuels.

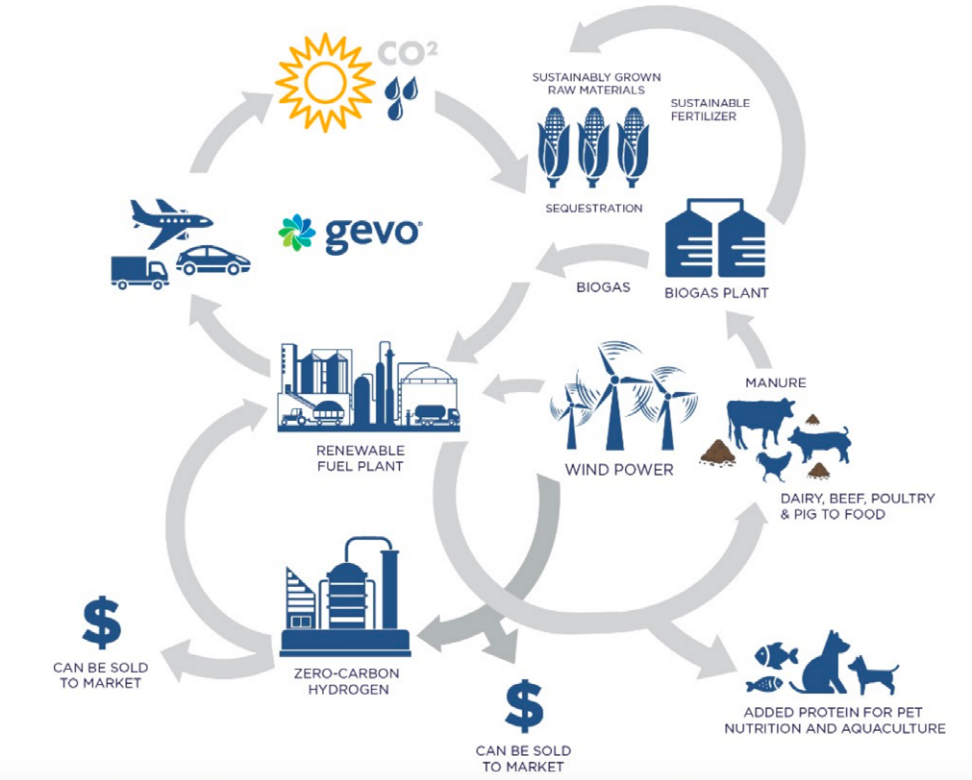
In particular, this is the objective of the **Net-Zero 1** plant, which is scheduled to open in 2024-2025. Verity Tracking has been developed to track all emission factors at the level of agricultural fields, transport and distribution until biofuel production, using scientific models such as the Argonne GREET[60] in the United States and the *Renewable Energy Directive II*[61] in Europe, among others.

These data are tracked *via* a blockchain and exchanged throughout the value chain in the form of tokens representing the product (raw or processed into biofuel), its carbon intensity as well as other traceability data, but also the amount of carbon potentially sequestered by partner farmers engaging in a regenerative agriculture approach.

An airline could buy proven low-carbon biofuel, but also link it to the "carbon credit" certificates directly linked to the production of these biofuels.

From the point of view or airlines, this is an innovative way to transform their traditional external carbon offsetting programs (e.g. by purchasing forestry carbon credits) into a reduction effort within their supply chain (*scope* 3[62]).

60 GREET, Argonne, retrieved Jul 20 2022, https://greet.es.anl.gov
61 "Renewable Energy - Recast to 2030 (RED II)", European commission, retrieved Jul 2022, https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en
62 Corporate carbon emissions are divided into three *scopes*: *Scope* 1 refers to all greenhouse gases emitted directly by the company, *Scope* 2 targets indirect and energy-related emissions, and *Scope* 3 concerns all indirect carbon emissions.



Gevo
Source : Gevo, https://gevo.com/

This is known as an "*insetting*" program[63]. Verity Tracking has signed agreements with technology partners such as FarmersEdge[64] and Google Cloud[65] in 2022 to strengthen its Measurement, Reporting and Verification (MRV) capabilities for tracked projects. The startup is developing a pilot program in 2022 with more than 20 farmers in the United States.

Finally **Traca-blé** is a French solution for wheat traceability launched by the Filière CRC® - Culture Raisonnée Contrôlée in partnership with the company **Crystalchain**. "Initially *accessible only to Filière CRC® members, this platform will strengthen the traceability chain by making it possible to consolidate data that was previously compartmentalized*[66]".

63 *Insetting* means assessing, reducing and offsetting a company's climate and environmental footprint by developing socio-environmental impact projects within its value chain, and leveraging them to build a sustainable society. Source: https://www.purprojet.com/presentation-what-is-insetting/

64 "Gevo and Farmers Edge Partner to Verify Sustainable Fuels from Low-Carbon Grain through Verity Tracking," Verity Tracking, retrieved Jul 2022, https://www.veritytracking.com/news/gevo-and-farmers-edge-partner-to-verify-sustainable-fuels-from-low-carbon-grain-through-verity-tracking/

65 "In a collaboration with google cloud, gevo to measure and verify the carbon intensity of biofuels across the supply chain utilizing verity tracking," Verity Tracking, retrieved Jul 2022, https://www.veritytracking.com/news/in-a-collaboration-with-googlecloud-gevo-to-measure-and-verify-the-carbon-intensity-of-biofuels-across-the-supply-chain-utilizing-verity-tracking/

66 "The crc industry launches "traça-blé", a blockchain solution to enhance its traceability data", Référence Agro, March 1, 2022, https://www.reference-agro.fr/innovation/la-filiere-crc-lance-traca-ble-une-solution-blockchain-pour-valoriser-ses-donnees-de-tracabilite/

There are many other projects and startups active in this field such as **Dovu** or the **Regen Network** (see Chapter "Environment and Climate").

Blockchain and agricultural markets

Another area of application of blockchain technologies in the agricultural field is the creation of trading platforms and markets.

Gavea has launched itself as one of the first OTC platforms (*Over-The-Counter*[67]) in the agricultural commodities market, particularly for corn and soybeans. After just one year of launch, the Brazilian startup announced that it has supported $2.3 billion in trading volume, or about 6 million tons of products[68].

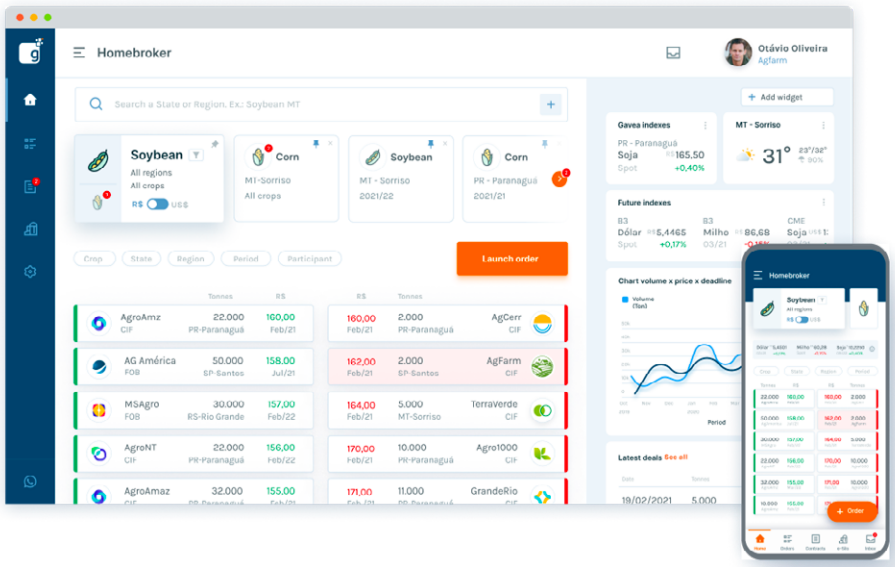
The platform promotes the social responsibility of the actors involved with Environmental, Social and Governance (ESG) criteria checks done at multiple levels as well as full traceability of counterparties on trading positions. The blockchain used also eliminates the middleman between buyers and sellers, reducing costs and increasing the speed of trading. The startup plans to tokenize other commodities such as sugar, wheat, cotton, and also plans to offer financial products such as credits for producers.

In India, **Agri10x** is another platform that offers an online cooperative protocol for the exchange of agricultural goods. Agri10x offers different modules for logistics, storage, marketplace or financial tools (*fintech*). The startup relies on the public blockchain Polygon since the end of 2021. Agri10x claims "*some 150,000 farmers and 6,000 suppliers reportedly trading with more than 4,200 traders in at least 80 commodities across 10 states in India*[69]*."*

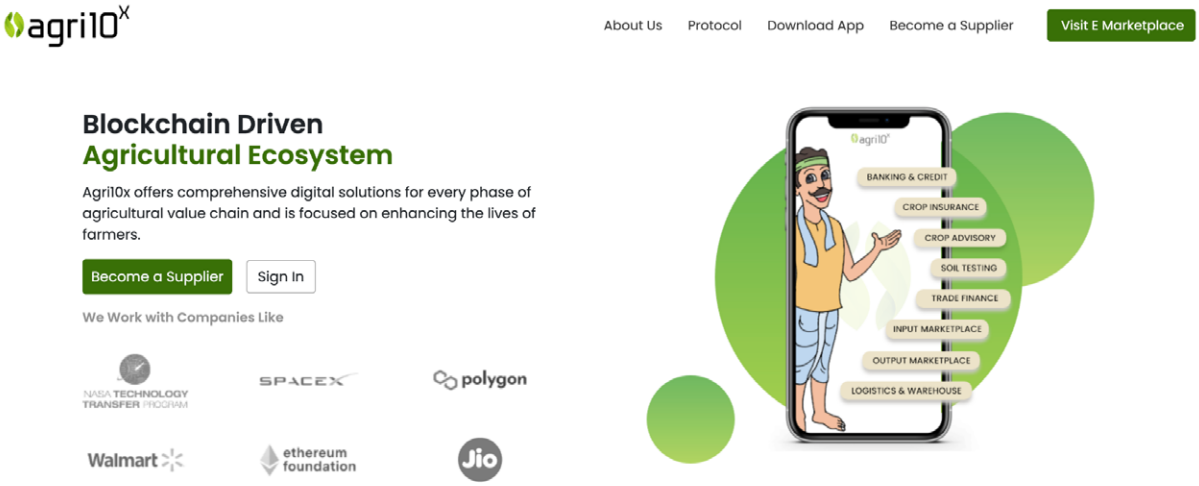
Agri10x is developing export channels for Indian farmers, including Dubai, Singapore, Malaysia, Qatar, Oman, Cambodia and Indonesia. The company wants to stimulate the development of agriculture in India and respond to all the problems of farmers, including by accompanying them on the steps of financing or agronomic management of soil and fertilizers.

Unfortunately, even if the white paper of the project presents the general concepts, little information is available about the exact functioning of the modules on the blockchain protocol.

67 An over-the-counter market or an OTC market that does not involve an intermediary.
68 "Gavea Blockchain commodities exchange exceeds US$ 2 billion in bids and offers", Redaçao Crania, Jun 21 2022, crania.com, https://crania.com.br/2022/06/21/gavea-blockchain-commodities-exchange-exceeds-2-billion-in-bids-and-offers/
69 "Blockchain Driven Agricultural Ecosystem", Agri10x, retrieved Jul 2022, https://www.agri10x.com/



Graphique 1. Source: “The Best Place to trade commodities”, Gavea, retrieved Jul 21 2022, https://gavea.com/



Graphique 2. Source: www.agri10x.com

ISSUES AND QUESTIONS

If blockchain initiatives are concerned with ensuring the traceability of agricultural products, one of the first issues is the accessibility of these technologies by the people primarily concerned: farmers and agricultural workers. The quality of the data in a supply chain depends largely on the information provided by each of the actors in the chain.

How can these tools be made accessible to a population that sometimes cannot read or write and does not own electronic devices? What about access to the Internet, the first condition for these systems to work? On the African continent, only 33% of agricultural areas are covered by 3 or 4G[1]. Hiveonline, which we discuss in the chapter "Peer-to-peer electronic money and programmable money", promotes the grouping of farmers in the form of cooperatives in order to facilitate their access to financing.

The system, which is based on the public blockchain Stellar, thus provides for the local recording of data without connection to the network and then updates the blockchain when connectivity is recovered.

The question of the type of blockchain used also arises. Agribusinesses tend to use private blockchains because they allow them to optimize their internal processes and obtain information within their own supply chain. However, this information held in distributed registries by these players may not be restricted to a single food chain.

The emergence of blockchain technologies first requires the acculturation of these actors, who are experimenting, on their own scale, with private or consortium blockchains. The form of coopetition promoted by public blockchains, i.e. a mix of competition and cooperation (data sharing on a common register open to all), must make its way in order to eventually prove the interest of using common repositories whose objective will be to ensure a better transparency of global supply chains (see also Chapter "Supply chains & logistics"). However, it seems that such a gathering of global players interacting through a single public registry, or several public blockchains that interact with each other, is still far away.

1 "The global divide in data-driven farming", Natura Sustainability, Nov 2020 https://www.nature.com/articles/s41893-020-00631-0

Another issue concerns the tokenization* of agricultural assets and raises the problem of the underlying productivism. Linking the issuance of a crypto-asset to the quantity of grain traded implies that larger sums will be directed towards the most productive farmers, who often adopt practices that are not very sustainable from an environmental point of view.

The case of soybeans in Argentina illustrates this contradiction perfectly. Indeed, the production of this commodity, tokenized or not, is for the time being carried out mainly for export, through a significant consumption of chemical inputs. Therefore, should other data on the quality of production be taken into account in tokenization?

Other projects focus on determining the exact environmental attributes of agricultural products in order to provide additional sources of income to farmers, rewarding them for their positive impact on the environment. The approach has great potential, particularly in terms of soil carbon regeneration and capture. However, there are still many obstacles to overcome, first and foremost those related to the monitoring of agricultural practices, for which quality data is not widely available. And even if these data are collected, their processing and verification often remain very difficult. While new technologies such as sensors linked to the Internet of Things (IoT) or geospatial imagery do exist, how can we verify by satellite the quantity of nitrogen fertilizer used or the diesel consumption of machines, two of the most important emission factors?

The risk would be to see the emergence of large quantities of tokenized carbon credits from agricultural projects for which the changes in practices and the actual carbon impact in the soil cannot be verified.

The amount of environmental benefits, particularly the quantification of soil carbon, depends greatly on the methodologies used. And there are dozens of them, more or less applicable, scientific or recognized. This is a problem of standards that can also be found in traditional carbon markets, where the quality of certificates and the evaluation of project data are crucial. And in the agricultural sector, there is still considerable room for improvement.

It is in this context that institutions such as the European Union and the FAO are launching initiatives for regional or global methodologies and

certifications in order to overcome the fragmentation of national and local certificates. Without this, it is difficult to create integrated and interoperable markets in which buyers and investors use the same reading grid and common units of quantification.

Even if many challenges still need to be solved, this proliferation of blockchain-based initiatives in the field of agriculture, from global players to small local agricultural cooperatives, suggests the potential of these distributed registries to build a more transparent and sustainable food production and distribution. In addition, the avenues for reducing greenhouse gas emissions at the agricultural level are varied, such as carbon @, the use of biomass, regenerative agriculture practices, the promotion of forestry for the rational use of forest trees, the use of more natural fertilizers, the reduction of pesticides, effluents and other chemicals or the promotion of organic farming (see chapter “Environment and climate”).

WEB 3.0, ARTS & SCIENCES

WEB 3.0, ARTS AND SCIENCES

Number of projects in the directory: 75

Number of active projects: 46

Name of active projects: Akasha World ; Arweave ; Binded ; Bittunes ; Blockchain My Art ; BlockchainyourIP ; Brave (Basic Attention) ; Breaker ; Bridgit ; CyberFM Mainstream For The Underground ; Decent ; DTube ; eyeWitness to Atrocities ; Fiducia FilmChain ; Gab ; Golem ; Gridcoin ; HashingDNA ; Inflow Music ; Klapcoin ; Lucidity Lympo.io ; MAP ; Mediachain ; Minds ; Monegraph ; Opus ; Peertracks ; PubliQ ; Resonate ; Royal ; Sapien ; Sia (ou Skynet) ; Steem ; Storj ; The Safe Network ; Tokit (Breaker) ; Torum ; Truepic ; Unbiased ; URights ; Vevue ; Vezt ; VitaDAO ; ZeroNet ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

The web allows the exchange of information and content, and public blockchains allow the exchange of value - but what about the impact of blockchains on the content, whether it is artistic, cultural, scientific or produced by journalists? What is the impact of the decentralized nature of public blockchains on the applications developed within these new ecosystems?

Blockchain initiatives are shaking up the current structure of the web and the storage and sharing of data or applications, but also the way value circulates when it is attached to digital content. The paragon of this is the wave of non-fungible tokens* (NFTs) since 2021: the registration of certificates of authenticity in public blockchains.

The distributed nature of public blockchains is also an opportunity to question the way in which information circulates between centralized and decentralized infrastructures: distributed hosting and storage, newsrooms, decentralized journalism and social media, digital content including music and videos whose ownership and copyright are now programmable, and finally decentralized science (DeSci), a movement that augurs a challenge to the concentration operated by a handful of intermediaries in the field of scientific publications.

These blockchain projects allow for new paradigms of creation, financing, monetization and circulation of content, all of which are deeply associated with what is being called Web 3.0.

Tim Berners-Lee spoke of this as early as 1994, calling it the Semantic Web, when he imagined a distributed network without a central authority, whose content would make sense both for people and for machines.[1]

Read, write, hold: from the static web to the decentralized web

The Web is one of the services made possible by the invention of the Internet, a worldwide network of computer networks, accessible to all and based on a standardized and open set of data transfer protocols. The World Wide Web is a public hypertext system operating on the Internet network, which was launched by Tim Berners-Lee in August 1991.

It is now common to account for the evolution of the web by distinguishing three periods, each of which corresponds to an evolution of its uses. Put simply, Web 1.0 allows people to **read**; Web 2.0 allows people to **read** and **write**; Web 3.0 allows people to **read**, **write** and **hold**.

Web 1.0, which the general public discovered in the mid-1990s, is equivalent to the publication of web pages on computer servers that can be consulted from a web browser. This web is said to be static, because it reproduces the consumption of traditional media of the time. In the same way that a printed newspaper is read, an Internet user reads, on the screen, a page accessible via the web.

Web 2.0, also called "participative web", marks the moment when the Internet user, from the 2000s onwards, is no longer just a passive consumer of information displayed on a screen but also becomes the producer of content, whether on blogs, wikis or the first social networks, with which they interact, share and exchange content of all kinds.

This period is characterized both by a wide democratization of web use among the general public and by the creation of digital giants that have capitalized on the exponential increase in the number of users attracted by the simplicity of the services offered, with the bias that, when the service is accessible for free, the model of these platforms is based on the massive exploitation of the personal data of the users of the service, most of the time in an opaque way.

As Web 2.0 services have become popular, they have centralized the major web applications in the hands of a few players such as Google, Meta (Facebook, Instagram, WhatsApp), Amazon, Uber, Airbnb or Blablacar.

These web giants have a business model akin to surveillance capitalism, the notion of which was popularized in 2014 by American economist Shoshana Zuboff, professor emeritus at Harvard Business School. Surveillance capitalism describes the evolution of industrial capitalism in the 20th century, led by the automaker Ford, to data capitalism, optimized by Google in

1 "Plenary at WWW Geneva 94", Tim Berners Lee, 1994, w3.org, https://www.w3.org/Talks/WWW94Tim/

	Web 1.0	Web 2.0	Web 3.0
Interaction	Lire	Lire - Ecrire	Lire – Ecrire - Détenir
Medium	Texte statique	Contenu interactif	Economie virtuelle
Organisation	Entreprises	Plateformes	Réseaux
Infrastructure	Ordinateur personnel	Cloud et mobile	Cloud Blockchain
Contrôle	Décentralisé	Centralisé	Décentralisé

The evolution of the World Wide Web

Source: "Blockchain Won't Save the World", Anthony Day, https://www.blockchainwontsavethe.world/about & https://www.linkedin.com/posts/anthonyjjday_blockchain-technology-innovation-activity-6874640878640615424-g3nx/

the 2000s. It is based on the systematic recording of individuals' personal data and their interactions, mostly without their knowledge.

This personal data is analyzed using powerful software (big data and artificial intelligence) in order to sell it to online advertisers.

Web 3.0, or the decentralized web, is an attempt to re-decentralize the web,[2] relying heavily on distributed ledger technologies and public blockchains to achieve this.

The advent of a decentralized web coincides with the desire of a multitude of actors to break free from the business model of the web giants.

However, Web 3.0 is not spared by its detractors, who denounce, sometimes rightly, the creation of new decentralized platforms that structurally operate services similar to those of Web 2.0.[3]

2 "What is Web3? Here Are Some Ways To Explain It To A Friend", James Beck, January, 2022, https://consensys.net/blog/blockchain-explained/what-is-web3-here-are-some-ways-to-explain-it-to-a-friend/

3 "Web3 explained in four questions", Olivier Clairouin, April 20, 2022 https://www.lemonde.fr/pixels/article/2022/04/20/le-web3-explique-en-quatre-questions_6122944_4408996.html

So what do blockchains bring to the creation, sharing and exploitation of digital content, whether in the fields of art, culture, journalism, social media or scientific publications? How do blockchains impact creation, sharing, and the way these contents are consumed, exchanged and valued?

How can blockchains help build resilient infrastructure, promote sustainable industrialization that benefits all, and encourage innovation, as promoted by Sustainable Development Goal 9?[4]

Will they help ensure that *"cities and human settlements are inclusive, safe, resilient and sustainable"*, Sustainable Development Goal 11?[5] How can they promote, as described in Sustainable Development Goal 16,[6] *"peaceful and inclusive societies, while ensuring access to justice for all"*, and build effective and accountable institutions at all levels?

Here follows an overview of blockchain initiatives in this area.

Decentralized Content/Data/Indexes

For more than a decade, the development of a hosting or cloud computing offer for companies wishing to outsource the management of the data they send and receive has represented a multi-billion dollar market, controlled by a handful of players including Amazon Web Services, Microsoft Azure, Google Cloud and Alibaba.

This cloud computing offer, which can be broken down into IaaS (Infrastructure-as-a-Service), PaaS (Platform-as-a-Service) and SaaS (Software-as-a-Service), depending on the extent of the data and services hosted remotely, consists, for the cloud operator, of hosting content, data and applications in server centers maintained by them.

The InterPlanetary File System (or IPFS) is a distributed peer-to-peer file system whose objective is to store information, such as files, websites, applications or data, in a completely decentralized, secure and confidential manner, thus protecting against any form of censorship. IPFS is not a blockchain but a data storage system perfectly adapted to blockchain applications that require access to content, which makes some people say that IPFS is a "*hard disk for blockchains*".[7]

4 SDG 9: Build resilient infrastructure, promote sustainable industrialization that benefits all, and foster innovation https://sdgs.un.org/fr/goals/goal9
5 SDG 11: Ensure that cities and human settlements are inclusive, safe, resilient and sustainable. https://sdgs.un.org/fr/goals/goal11
6 SDG 16: Promote peaceful and inclusive societies for sustainable development. https://sdgs.un.org/fr/goals/goal16
7 "What is IFPS? The hard drive for Blockchain", iCommunity, Retrieved May 23 2022, https://icommunity.io/

More precisely, IPFS seeks to create a persistent[8] and distributed web that no longer relies on the location of content but on the content itself. Today, a search for information on the web consists of asking a search engine "where the content is" in order to identify the URL of the machine where the data or the page is hosted; a search in IPFS consists of asking the system for "the content we are looking for", identified by a unique and permanent cryptographic hash*. *"In this way, the system takes advantage of physical proximity. If someone very close to me has what I want, I will get it directly from them instead of connecting to a central server"*[9] explains engineer Karan Kwatra.

Created in 2014 by Juan Benet, IPFS is an open source protocol that can largely grow alongside the Hypertext Transfer Protocol (HTTP), invented by Tim Berners-Lee in 1991. IPFS is already widely used,[10] whether by blockchain initiatives or otherwise, in sectors and services as diverse as social networks, web browsers, Content Delivery Networks (CDNs), NFTs*, identity systems, the Internet of Things, decentralized finance, marketplaces, or in the fields of data and machine learning.

For example, **Filecoin,** developed by Protocol Labs, the originator of IPFS, is a decentralized cloud service. IPFS can be used by websites unrelated to blockchains, such as Wikipedia, which has developed a mirror of their website in order to give access to the online encyclopedia in countries where it is censored. **Audius** is a decentralized music streaming system whose content is hosted on IPFS.

Decentralized Hosting of Dapps and Blockchain Nodes

Most public blockchain nodes today have some degree of architectural and/or political centralization (see Introduction - What is a Blockchain?).

Architectural centralization means asking the question of how many physical computers the system consists of. Political centralization, on the other hand, consists of asking how many individuals or organizations have ultimate control over the computers that make up the system.[11]

However, many public blockchains host some of their network nodes on Virtual Private Servers (VPS), which amounts to centralizing their system once again since the physical computers are

en/what-is-ifps-the-hard-drive-for-blockchain/
8 "Persistence, permanence, and pinning", IPFS doc, retrieved Jul 21 2022, https://docs.ipfs.io/concepts/persistence/#persistence-versus-permanence
9 "What is IPFS?", Karan Kwatra, Mar 15 2018, retrieved May 23 2022, https://medium.com/wolverineblockchain/what-is-ipfs-b83277597da5
10 "Ecosystem directory", IPFS, retrieved Jun 3 2022, https://ecosystem.ipfs.io/?results=70
11 "The meaning of Decentralization", Vitalik Buterin, Medium, Feb 6 2017, https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274

hosted by Amazon Web Service or other centralized cloud services. To remedy this contradiction, some startups offer public blockchains a distributed hosting solution for their applications, such as **Substratum, The Safe Network**[12] (see chapter "Electronic Communications and Telecommunications") or **DAppNode,** which offers a service for deploying and hosting decentralized applications (DApps), peer-to-peer applications or blockchain nodes.

DAppNode[13] is a free and open source platform for *"deploying and hosting DApps*, P2P clients and blockchain nodes"*. For the user, DAppNode takes the form of a platform that allows them to deploy decentralized applications and blockchain nodes on their own machine and access them directly via a decentralized protocol without using gateways or centralized third parties.

DAppNode has a DAppStore from which available applications can be downloaded and installed in a few clicks. DAppNode also allows its users to earn tokens by participating in the maintenance, validation and sharing of resources of certain decentralized networks.

Decentralized Cloud

The traditional cloud services market is entirely dominated by a few American and Chinese giants, called hyperscalers. At the end of 2019, a dozen actors shared 77% of the global market. In 2020, Amazon Web Services (AWS) held 31% of the cloud infrastructure market, followed by Microsoft Azure (20%), Google Cloud 6%, and Alibaba 5%.[14]

In Europe, in the first half of 2020, 68% of European enterprise cloud infrastructure spending is captured by Amazon Web Services (53%), Microsoft Azure (9%) and Google (6%), while France's OVHcloud, the European leader in private cloud, holds only 4%.[15] Faced with this offer of centralized hosting infrastructures, a so-called decentralized cloud is developing, carried by several actors such as **Skynet (Sia)**, **Storj** and **Arweave,** even if their scope remains limited to date.

If we compare centralized data center storage and decentralized data storage, the former relies on infrastructure built *ex nihilo* to operate the service, whereas the decentralized cloud relies on storage and bandwidth capacities already existing and provided at the edge of the network by the individuals

12 "How Does it work?", The Safe Network, retrieved Jun 3 2022, https://safenetwork.tech/
13 "What is DAppNode?", DAppNode, retrieved Jun 3 2022, https://docs.dappnode.io/get-started/intro
14 "Global cloud services spend exceeds US$50 billion in Q4 2021", Canalys, Feb 3 2022, https://www.canalys.com/newsroom/global-cloud-services-Q4-2021
15 "The European Cloud: major challenges for Europe and five scenarios with major impacts by 2027-2030", Jacques-André Fines Schlumberger, The European Journal of Media and Digital Affairs -N°57-58 Spring - Summer 2021, https://la-rem.eu/2021/10/le-cloud-europeen-de-grands-enjeux-pour-leurope-et-cinq-scenarios-avec-des-impacts-majeurs-dici-2027-2030/

or companies operating the service. The hardware investment required to build a data center disappears when the decentralized hosting service relies on the already existing resources on the network, whose capacities are *de facto* much higher.

Although companies have been migrating their data to specialized third parties for several years, the cost of hosting this data increases considerably as it accumulates. However, *"there is so much excess capacity in private storage today that costs can be kept low and do not need to increase as data grows"*.[16]

Several blockchain initiatives are taking advantage of these new data hosting architectures.

Skynet is built on top of a public blockchain called **Sia**, launched in 2015. It's an open protocol for hosting decentralized data and applications. The project's founders describe their service as an *"Airbnb for data storage"*.[17] People who need storage space (called Renters) pay, using a token called **Siacoin**, to store their data on the hard drives of people who have unused storage space (called Hosts).

The service operated by Sia consists of encrypting the data, splitting it into packets, and distributing it to all the computers that participate in the system. Since there is no central authority, the content cannot be censored. Similar is **Storj DCS**, for Decentralized Cloud Storage, whose first white paper was published in December 2014 and updated in 2016, and whose platform was launched in late 2018.[18]

People with unused storage space can thus participate in the decentralized cloud network by becoming a node in the network and are paid in Storj tokens for the service rendered. To quote one last project, **Arweave** is a decentralized storage network *"that aims to provide a platform for permanent data storage"* and describes itself as *"a collective hard drive that never forgets"*.[19]

Introduced as Archain in August 2017, renamed to Arweave in February 2018, the service launched in June of that year and hosts a number of decentralized applications and community platforms.

16 "Comparing the Economics of Centralized and Decentralized Cloud Storage", Christine Ackley, Storj, Jul 15 2021, https://www.storj.io/blog/comparing-the-economics-of-centralized-and-decentralized-cloud-storage
17 "Skynet Overview", Siasky, retrieved May 30, 2022, https://support.siasky.net/
18 "Getting Starting on DCS", Storj, retrieved May 30, 2022, https://docs.storj.io/
19 "Arweave", Arweave.org, retrieved May 30, 2022, https://www.arweave.org/

Decentralized Video Streaming

Live Peer, founded in New York in 2017 and built on the public Ethereum blockchain, is a decentralized live video streaming platform. One of the biggest expense items for a streaming video platform is the cost of transcoding videos. Video transcoding is the process of optimizing the raw file of a video to reformat it to different sizes to optimize playback regardless of the viewer's bandwidth and device.

According to LivePeer, *"this process costs about $3 per stream per hour for a cloud service like Amazon's, up to $4,500 per month for a media server, and up to $1,500 per month for a Content Delivery Network".*[20] The promise of LivePeer is a protocol for IT developers to deliver live or on-demand video service at a cost reduced by a factor of fifty.[21]

When a person records or films live, from an application that has integrated the Livepeer service, the video stream is sent over the peer-to-peer network and transcoded by some of the nodes in the network, called "orchestrators". The orchestrators run software that makes their computer resources (CPU, GPU and bandwidth) available to transcode and distribute the video over the Livepeer network.

For this activity, they are paid in Ether or in stable crypto-assets* such as DAI. To operate on the network, orchestrators first acquire a token called Livepeer token (LPT). The more LPT tokens an orchestrator has, the more transcoding work it is able to perform on the network and get paid.

A second type of user, called "delegates", are holders of LPT tokens who participate in the security of the network by placing their tokens with the orchestrators of their choice. Thus, when a media uses Livepeer's video streaming service, it pays a fee to the network, much lower than on a centralized platform, which will be passed on to the orchestrators and delegates.

The Livepeer protocol also creates new LPT tokens and distributes them among orchestrators and delegates based on their participation relative to other network members, thus *"increasing network ownership among those who participate and decreasing it among those who do not participate".*[22] These new tokens are created according to an inflation rate that automatically adjusts according to the number of tokens put into play relative to the total supply in circulation, in order to, among other things, *"find a healthy trade-off between network security and token liquidity".*[23]

20 "Livepeer", Livepeer, retrieved May 30 2022, https://livepeer.org/primer
21 *Ibid.*
22 *Ibid.*
23 *Ibid.*

According to Livepeer, 4,250 delegates are currently securing the network.

While all of these services propose to rethink how content, data, and applications are hosted, one U.S. company, **Mediachain**, founded in 2016 and acquired by Spotify in 2017, is building a decentralized data index (see below). An index is the data structure used by a database management system to quickly find data within it.

Media and Journalism

The news media and journalism, especially since the advent of social networks, are adapting to the loss of their monopoly on public speech since the 2010s and the advent of the participatory web. The challenges facing the news media are numerous: the fight against false information and the crisis of confidence to which some are subjected, the monetization of their content, the difficult relationship with the web giants (powerful vectors of audience, whether from Google for the search for information, or from social networks, including Meta ex Facebook), and the advertising pressure brought about by programmatic advertising, whose model is based on ever more advanced profiling of their audience.

Seven years ago, several blockchain projects led by journalists, and since abandoned, were thus born, among which **Civil.co**, created in 2016 and whose activity ceased in 2020, or **Po.et**, created the same year and stopped in 2019.

The Civil.co project was to create a token offering the possibility for journalists to be paid directly by their readers, without going through a media outlet. According to its president at the time, Matthew Iles, the idea was to *"leverage blockchains and the crypto-economy and create a free and independent press platform involving only journalists and citizens, with no advertising or third parties in the business model".*[24]

The open source project Po.et, on the other hand, presented itself as *"a decentralized protocol for content ownership, discovery and monetization in the media"*. Po.et was aimed at content creators (journalists, media, YouTubers, podcasters, bloggers, artists...) to certify and protect their works, by time-stamping them in the Bitcoin blockchain and associating metadata (name of the author or first editor), as well as the exploitation licenses. This information was stored via the free software InterPlanetary File System (IFPS) (see above). It then becomes possible to trace the use of content and to check if the copyright has been respected.

24 "What synergies between blockchains and cultural industries?", Jacques-André Fines Schlumberger, The European Journal of Media and Digital Affairs -N°49 Winter 2018-2019, https://la-rem.eu/2019/03/quelles-synergies-entre-les-blockchains-et-les-industries-culturelles/

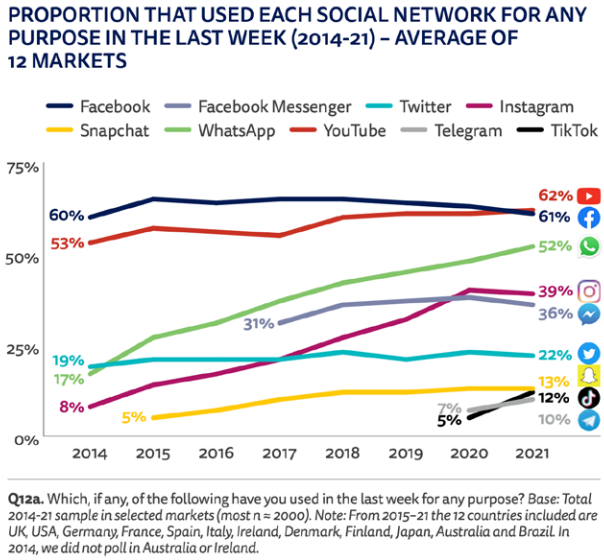
In the domain of the fight against false information, a French company, **Block Expert**, and **MadNetwork,** created in New York in 2017, launched labels named **Safe.press** for the first and **Full Transparency** for the second.

They allowed the certification of companies' press releases, the misuse of which can cause significant harm. To cite just one example, on November 22, 2016, a press release from the Vinci Group announced a revision of the financial accounts, as well as the dismissal of its CFO, quickly causing the share price to plunge by 19%, or the equivalent of 6 billion euros.

However, the press release was false. The label Safe.press, built on a private blockchain in 2019, developed on Hyperledger, ceased operations in early 2020, as did **MadNetwork.**

It is clear that the decentralized nature of blockchains has not found an echo in the traditional news media. However, some innovations have emerged in the field of social networks and micro-payments.

Networks & Social Media



Source: Reuters Institute Digital News Report 2021 10TH Edition Nic Newman with Richard Fletcher, Anne Schulz, Simge Andı, Craig T. Robertson, and Rasmus Kleis Nielsen https://reutersinstitute.politics.ox.ac.uk/sites/default/files/2021-06/Digital_News_Report_2021_FINAL.pdf

As of January 2022, 4.62 billion people worldwide use one or more social networks,[25] representing 58.4% of the world's population. The most popular social networks are owned by Meta (Facebook), Google, Twitter and Snap Inc.

Their huge audience and commercial success coincide with a series of criticisms, including content manipulation, false information, misuse of advertisements for political purposes, censorship, either directly by the social network or by a country that decides to

25 "Digital 2022: another year of exceptional growth", We Are Social, retrieved Jun 3 2022, https://wearesocial.com/fr/blog/2022/01/digital-2022-une-nouvelle-annee-de-croissance-exceptionnelle/

suspend or permanently cut off access to its citizens, the business model, and criticisms based on the collection and analysis of personal data without the knowledge of their users.

Blockchain projects are working to propose new models that address some of these issues, notably by creating a decentralized social network, such as **Steem, Hive** or **Dtube**, but also micropayment solutions such as **Kin**.

In its white paper published in August 2017,[26] Steem bills itself as *"a blockchain-based public content incentive platform"*. Steem is a public blockchain on top of which decentralized applications (dApps*) are built, the first of which, **Steemit,** often compared to the social network Reddit.com, was launched on July 4, 2016.

Steemit bills itself *"as the first publicly accessible database for content stored immutably as plain text, with a built-in incentive mechanism"*.[27]

The blockchain is public and open source.[28] The consensus mechanism implemented is Delegated Proof of Stake (DPoS*).

Steemit remunerates both the content creators on the platform and the people who vote and like the content in order to identify quality content through a system combining "pool rewarding" coupled with a "voting system".[29]

STEEM tokens are generated at a fixed rate of one block every three seconds. Specifically, the Steem blockchain has been generating STEEM tokens at a fixed rate of 9.5% per year since December 2016, with the rate of inflation decreasing by 0.5% per year before stopping when it reaches 0.95% in 20.5 years.

All STEEM tokens generated are allocated as follows: 75% are sent to the reward pool, and are distributed to content creators and those who vote for that content. 15% of the tokens are distributed to those who already own a certain type of token, called Steem Power (see below), and the remaining 10% are distributed to nodes on the Steem blockchain, called delegates, elected to validate transaction blocks on the blockchain.

Steemit relies on three tokens managed via the public Steem blockchain: 1. the Smart Media Token (SMT) called STEEM, the native token of the blockchain of the same name, 2. the Steem Power (SP), a locked version of STEEM that gives the account influence on the platform,

26 "Steem White Paper", Steem, August 2017, https://steem.com/SteemWhitePaper.pdf
27 "Steem Developer Portal", Steem, retrieved June 3, 2022, https://developers.steem.io
28 "Steem/Steemit", Github, retrieved June 3, 2022, https://github.com/steemit/steem
29 "A protocol for enabling smart, social currency for publishers and content businesses across the internet", Steem, Bluepaper, retrieved May 31, 2022, https://steem.com/steem-bluepaper.pdf

and 3. the Steem Backed Dollar (SBD) whose value corresponds to one dollar in STEEM. When a writer receives a reward for the content they publish, or a curator for the vote they make, half of the reward is paid out in the form of Steem Power (SP), and the other half in the form of Steem Backed Dollar (SBD), with the ability to convert the tokens to each other or to STEEM.

When a user votes on content, their influence on the distribution of the reward pool is directly proportional to the amount of Steem Power (SP) they hold. The most active users who keep their Steem Power are rewarded with more overall influence on the network.

The innovation brought by **Steemit** is to have created a social network that allows content publishers not to rely on an advertising model, to natively support micro transactions with almost instant settlement and almost zero transaction fees, and to operate a positive reinforcement loop between those who publish and those who vote, both being rewarded for their activities.

In March 2020, Steemit was bought by the Tron Foundation, headed by Justin Sun, which caused the discontent of part of the Steem community and resulted in a hard fork* of the blockchain, giving birth to **Hive.**

According to their designers, **Hive** is *"a blockchain with DPOS* (Delegated Proof of Stake) *governance, built from a copy of Steem's source code and operating completely independently of the pre-existing blockchain".*[30]

Whether on public blockchains such as STEEM or Hive or otherwise, project developers are building decentralized applications (dApps*), including **D.tube**, a decentralized video platform, and decentralized social networks such as **Peakd**[31] or **Ecency**.[32]

The **DTube** platform offers a video sharing network where some users post videos while others determine the interest of the content. Not only can users tip the content creators, but also their "likes" and comments are paid by the platform, like on Steemit.

The autonomous platform is controlled by ten people or leaders,[33] chosen by the community, who are in charge of producing new blocks of transactions. The platform describes itself as censorship resistant, free from the advertising model, and claims not to collect user data while distributing 90% of the value created.[34]

These decentralized content platforms, based on public blockchains designed to promote micro-transactions around content managed by a community of

30 "Announcing the Launch of Hive Blockchain", hiveio, March 17, 2020, retrieved May 31 2022, https://peakd.com/communityfork/@hiveio/announcing-the-launch-of-hive-blockchain
31 "Decentralized Social Media with True ownership", Peakd, retrieved July 21, 2022, https://peakd.com/
32 "Welcome to Ecency", Ecency, retrieved July 21, 2022, https://ecency.com/
33 This figure may change in the future.
34 "A new model: the social blockchain", D-Tube, retrieved July 21, 2022, https://token.d.tube/

users, restructure the dynamics at work between their users and propose new paradigms of compensation and reward for each person's participation.[35]

One of the fundaments of these applications is their capacity to monetize the interactions of their users, not without their knowledge as is the case of traditional social networks, but through tokens, exchanged directly between users within communities.

Art, Music & Video

Sustainable Development Goal 11, *"make cities and human settlements inclusive, safe, resilient and sustainable"* has as its ambition, through its target 4, the *"strengthening of efforts to protect and preserve the world's cultural and natural heritage".*[36]

The art, music, film and cultural industries in general have been deeply impacted by the development of the web. After the promises of disintermediation between artists and their public in the 2000s, it is clear that today, value is increasingly captured by more and more powerful intermediaries. To give just one example, while the music industry generates 43 billion in annual revenue, only 12% goes to artists.[37]

One of the reasons for this imbalance is the number of intermediaries between artists and their audiences, and the way in which value flows between them.

A number of blockchain initiatives are seeking to shake up this hyper-centralized landscape by giving the creator of intellectual works the opportunity for new sources of financing, better control of rights by the artist themselves, the management and programmability of associated rights and microtransactions, and the acceleration of payment times.

These blockchain initiatives are based on the development of NFTs*, driven by the craze they have been generating since the beginning of 2021, but also on the creation of new ecosystems directly linking artists and audiences through the tokens of decentralized platforms.

As we have seen in the chapter "Aid, Charity and Philanthropy", non-fungible tokens (NFT*), associated with the field of art and digital content, inaugurate new forms of financing projects with a social and/or environmental dimension, whether they are carried by existing organizations or by communities of people united around a cause.

35 "How The Blockchain Can Solve Social Media's Biggest Problems", Sunny Dhillon, Forbes, February 28, 2018, https://www.forbes.com/sites/valleyvoices/2018/02/28/how-the-blockchain-can-solve-social-medias-biggest-problems
36 Sustainable Development Goal 11, United Nations: Make cities and human settlements inclusive, safe, resilient and sustainable, https://www.un.org/sustainabledevelopment/fr/cities/
37 "Introducing $AUDIO, The Audius Platform Token", Oct 8 2020, https://medium.com/audius/introducing-audio-the-audius-platform-token-2c575215b439. Retrieved June 1, 2022.

How does a non-fungible token (NFT) work?[38]

While bitcoin and the majority of crypto-assets issued on a public blockchain are fungible, i.e. any of these tokens can be exchanged for another, non-fungible tokens refer to a unique digital asset.

They are issued on a public blockchain such as Ethereum, Tezos or Cosmos, using a smart contract* and therefore rely on the intrinsic qualities of public blockchains. However, in addition to their unfalsifiable, traceable, interoperable and exchangeable character, a non-fungible token is unique and indivisible.

This uniqueness makes it possible to certify the authenticity and ownership of original objects, including works of art, physical or digital collectibles, domain names, receivables and even real estate.

In order to come into existence, like national currency issued by a State, an NFT is first minted in a public blockchain, and then eventually burnt, i.e. deleted. Minting an NFT consists of using a wallet and a smart contract* to register the token and its identification data in a public blockchain so that it becomes immutable, exchangeable and also searchable and verifiable by anyone.

Several public blockchains such as **Binance Smart Chain**, **Polygon**, **EOS**, **Flow**, **Polkadot**, **Tezos**, **Tron** or **WAX** are used to mint NFTs, the most popular being the **Ethereum** blockchain.

On Ethereum, an NFT is the object of a smart contract* that applies the ERC-721 or ERC-1155 specifications. Each non-fungible token has an identifier in the smart contract*. The association of the contract address and the identifier then becomes a globally unique identifier, a hash. Only the hash*, and not the work, is stored in the Ethereum blockchain and is used to prove the ownership of the content to everyone.

Acquiring an NFT does not prevent the digital work, image, animation, trading card or video from being viewed and shared by others. The standard also provides for a transfer function between portfolios to enable NFT transactions while showing all owners at each trade.

In addition, metadata associated with the NFT provides descriptive information. When an NFT corresponds to a concert ticket, the metadata may indicate, for example, the date of the event and the type of ticket, in addition to the name of the concert, its coordinates and its programme.

The work itself, if it is digital, is accessible on the web, risking its disappearance. It can also be hosted via decentralized storage systems, such as IPFS (see above), to guarantee perennial access.

38 “NFT”, Jacques-André Fines Schlumberger, The European Media and Digital Review, N°57-58 Spring - Summer 2021. https://la-rem.eu/2021/07/nft/

Blockchains can be used as distributed registries to record authorship and any digital file naturally lends itself to having its fingerprint recorded in a public blockchain. Many companies have been offering this type of service for several years, such as **Binded** in the United States since 2016, **BlockchainyourIP** in France since 2017 or **HashingDNA** in Spain since 2018.

The process consists of creating a certificate including a digital fingerprint of the document, in the form of a hash* (mathematical function that transforms any content into a hexadecimal number and that, at the slightest change in the content, will give a completely different number), the date of its registration in the blockchain used as well as the transaction number and the number of the block where the digital fingerprint of the document was registered.

Beyond the proof of authorship of a work, blockchains, and especially smart contracts*, make it possible to imagine new systems for managing copyright, which is regularly denounced by artists, whose payments by collective management societies can take months, even years, or never reach the beneficiaries.

Most artists also denounce the low amounts received for listening on streaming platforms, whether audiovisual or musical. According to Digital Music News, the average amount paid by YouTube to artists for each listen has increased from $0.0006 in 2017 to $0.00074 in 2019 and the average amount paid by Spotify is $0.004.[39]

Blockchains, it seems, would not only bring transparency to a particularly opaque value chain by cutting out certain intermediaries, but would also considerably simplify the payment of artists while adapting to new uses, particularly those related to music streaming.

Mediachain,[40] founded in New York in 2016, is a decentralized data index. Mediachain defines itself as *"a single logical space, organized by topic or application, that allows multiple participants to publish and discover data without a central point of control or failure. In other words, Mediachain allows multiple participants to collaborate on data indexes in a fully decentralized manner".*[41]

One of the problems for which MediaChain is trying to provide an answer is the opacity of copyright allocation, particularly in the field of music.

39 "How Much Does Spotify Pay Per Stream? Here's the Latest Data (Updated for 2022)", Dylan Smith, digitalmusicnews.com, August 17, 2020, https://www.digitalmusicnews.com/2020/08/17/how-much-does-spotify-pay-per-stream-latest/
40 "Mediachain", Mediachain, retrieved June 21, 2022, http://www.mediachain.io/
41 "Mediachain an open, universal media library", Mediachain, retrieved June 21, 2022, http://docs.mediachain.io

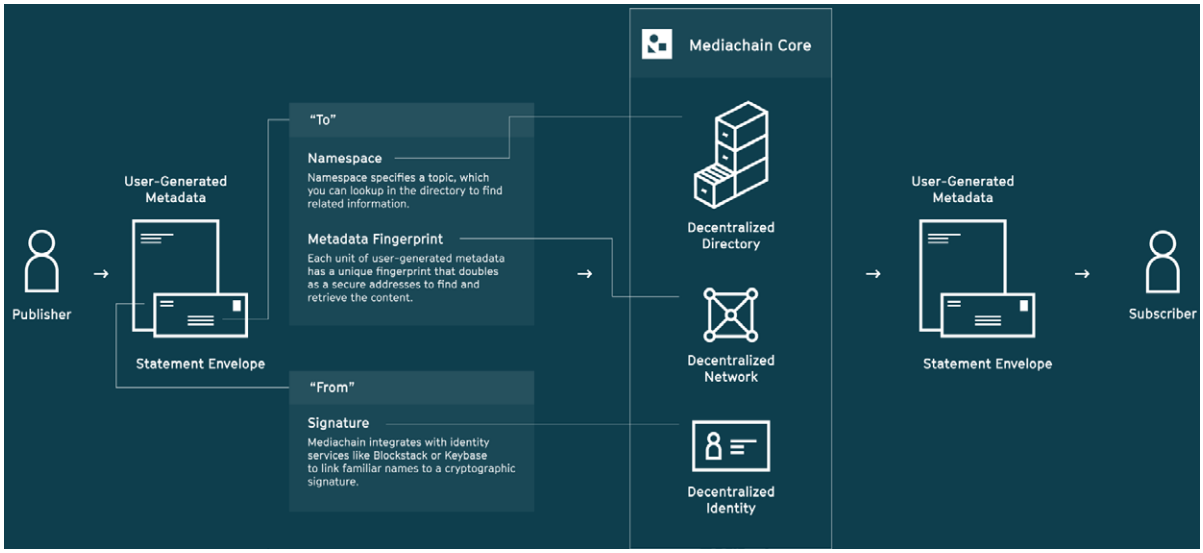


Diagram of how to use Mediachain
Source: "Mediachain", retrieved June 1, 2022, http://www.mediachain.io/

The idea is to create a decentralized, common, open and distributed index of copyright information, previously scattered among the various music labels. MediaChain's open registry uses the metadata linked to the work (artist's name, type of contract, copyright, ...) as a reference in an index accessible to all professionals.

This metadata is then hashed and stored in IPFS (see above). MediaChain would then provide access to a mapping of the metadata related to the works stored in IPFS. In 2017, Mediachain was acquired by Spotify, which has been regularly condemned for copyright infringement, although it is not possible to know the progress of the project at this time.

These centralized music streaming platforms are also seeing the emergence of new players in their market. **Audius,**[42] founded in 2017, is a peer-to-peer music streaming platform, connecting artists directly with their audience, for which an iOS or Android app has been available since 2020. Originally built on Ethereum, Audius migrated to the public Solana blockchain[43] in 2021. Audius works like a traditional streaming platform: artists are paid according to the number of listens generated on the platform and receive a much higher percentage of remuneration than on traditional platforms like Spotify or Deezer. According to the platform, 90% of the revenue generated on Audius is paid back to the artists.[44]

42 "Audius", Audius, retrieved June 1, 2022, https://audius.co/
43 "The music industry, future victim of the Blockchain Revolution? Audius (Audio) at the top of the charts!", Hellmouth Banner, Le Journal du Coin, October 26, 2021, https://journalducoin.com/actualites/audius-donne-le-tempo-dune-industrie-musicale-blockchainisee/
44 "Audius, the platform that best pays artists (and listeners)?", Cloé Gruhier, Hauméa Magazine, retrieved June 1, 2022, https://www.haumeamagazine.com/audius-la-plateforme-de-streaming-qui-remunere-le-mieux-

Artists, who are paid with Audius' native token, the $AUDIO, could soon create their own token, indexed to the $AUDIO.

The governance of the platform is directly ensured by members of the community who put a sum of money on the line (proof of stake*) in $AUDIO and whose voting rights depend on the amount invested. Within the Audius network, discovery nodes are nodes in charge of registering new artists on the platform, encouraging the addition of new content creators directly by the community.[45]

Content nodes are nodes in charge of validating the uploading of musical content on the platform.[46] Both receive $AUDIO for their participation in the network. To encourage community members to secure the platform by tying up their tokens (proof of stake*), the more users save their $AUDIO, the more they unlock features on the platform, such as access to NFT* collections or privileged access to certain content. Audius, which claims more than 6.2 million active users in May 2022, is still far from its competitors such as Spotify or Deezer, but it is clear that the project is gaining momentum.

Whether in the field of music or even cinema, some blockchain initiatives aim to experiment with new sources of financing by involving the general public.

Inflow music, which uses Livepeer (see above), offers artists, sportsmen and personalities the possibility to create their own token in order to be directly financed by their fans who, in exchange, have access to exclusive content, meetings and special events accessible only to token holders. Certain content, sold as NFTs*, can then be resold to other buyers, including a 15% commission for each transaction.

Inflow music is a way for artists to interact with their fans without intermediaries while benefiting from new sources of revenue. Inflow music, whose service is still in development, is being incubated by the Web 3.0 startup gas pedal Tachyon Accelerator, supported by ConsenSys and Protocol Labs.[47]

Vezt or **Royal** offer artists the possibility to sell a portion of the future royalties from their songs streamed on major listening platforms such as Spotify, Deezer or Apple Music.

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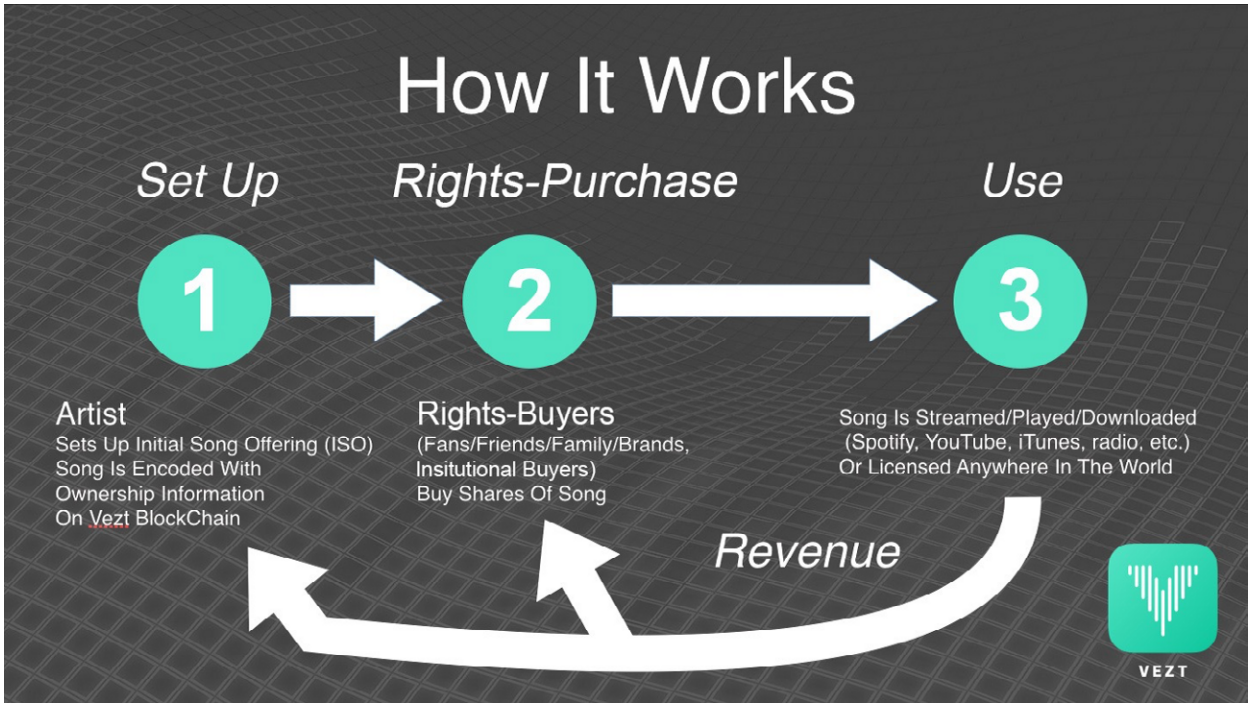
les-artistes-et-les-auditeurs/#:~:text=Audius%20is%20a%20platform%20of,%C3%A0%20the%20crypto%2Dmoney

45 "Audius, the platform that best pays artists (and listeners)?", Cloé Gruhier, Hauméa Magazine, retrieved June 1, 2022, https://www.haumeamagazine.com/audius-la-plateforme-de-streaming-qui-remunere-le-mieux-les-artistes-et-les-auditeurs/#:~:text=Audius%20is%20a%20platform%20of,%C3%A0%20the%20crypto%2Dmoney

46 *Ibid.*

47 "How Inflow Created the First Music Platform for the Web3 Economy", Ivan Kreimer, Livepeer Video Services, May 26, 2022, https://livepeer.com/blog/how-inflow-created-first-music-platform-web3-economy



How Vetz Works ?

Source : Vezt Inc, September 18, 2017, https://medium.com/@vezt/the-real-greatest-hit-how-vezt-works-cb66aef74d67

Vezt,[48] founded in Los Angeles in the United States in 2017, is a mobile music streaming app built on the public Ethereum blockchain, allowing artists to offer a portion of their royalties for sale to fans, who are then compensated in proportion to their initial investment.

Specifically, Vezt puts up for sale certain copyrights in a crowdfunding campaign they call "Initial Song Offering™ (ISO)",[49] registers the artist's rights with rights collection companies and digital platforms, and then pays the rights back as they go along, via smart contracts*, to the artists and buyers of the rights according to this scheme (see below).

For example, an artist chooses a song, the date, and the amount for which the rights will be sold, for example $1,000 for 1% of their royalties, as well as the length of time the buyers will be paid: 3 years, 5 years, 10 years or even lifetime. Buyers, including fans, music professionals and brands, purchase these rights and the artist receives the funds immediately.

The song's rights information is then encoded on Vezt's blockchain and *"royalties are collected both from rights collection companies in 137 countries around the world and from STEM. is*,[50] *a service that aggregates digital performance royalties from* streaming

48 "Vezt", Vezt, retrieved June 1, 2022, https://vezt.co
49 "The Real Greatest Hit: How Vezt Works", Vezt Inc, Medium, September 18, 2017, https://medium.com/@vezt/the-real-greatest-hit-how-vezt-works-cb66aef74d67
50 "Stem brings clarity to your modern music business", Stem, retrieved July 11, 2022, https://stem.is/

services such as Spotify, iTunes, YouTube, Pandora, etc".[51]

Royal does the same thing. It is a platform that sells the rights to songs created by artists in the form of NFTs*. Artists choose what percentage of the song's future royalties they want to put up for sale and the public buys those streaming music royalty rights in the form of NFTs*.

As a song is played on the various streaming platforms - Spotify, Apple Music, Youtube, etc, it generates royalties that go back to the original investors according to the terms defined in the NFT*. For accessibility, the general public can purchase NFTs* using the stablecoin* USDC on Polygon (Matic) and a wallet* like Metamask, or pay with a traditional payment card, the platform taking care of creating a wallet for the user.

The artist will also be able to benefit from a certain number of advantages linked to the token. The NFT* can then be resold to a new buyer who benefits from the royalties and advantages associated with the token. The project is built on Polygon, a layer 2 based on the Ethereum public blockchain. Created in early 2021, Royal had 120,000 accounts as of August.

In two rounds of funding in the same year, Royal raised $71 million, including some from artists.[52]

These two initiatives, Vetz and Royal, seem to be part of the continuity of the system set up by the traditional copyright collection organizations, but renew access to copyright not only for music professionals but for their fans and individuals.

It is also possible to imagine, thanks to smart contracts*, assuring multiple ownership of copyright. The Ethereum community has been developing since September 15, 2020 the EIP-2981,[53] an "NFT Royalty Standard" to allow smart contract* NFTs[54] to indicate the royalties corresponding separately to the original creators and to the owners of copyright. The standard *"allows contracts, such as NFTs that support the ERC-721 and ERC-1155 interfaces, to report a royalty amount to be paid to the NFT creator or rights holder each time the NFT is sold or resold"*.[55]

While royalty payments are not yet automated and remain manual, the standard notes that, in a future EIP,[56] a mechanism will be proposed to resolve automatic payment and notifications.

51 "The Real Greatest Hit: How Vezt Works", Vezt Inc, Medium, September 18, 2017, https://medium.com/@vezt/the-real-greatest-hit-how-vezt-works-cb66aef74d67
52 "Combining Music Rights with NFTs: Royal Raises Big Money", Carpenter WellingtonPLLC, Lexology, December 9, 2021, https://www.lexology.com/library/detail.aspx?g=92d81306-ca86-47ca-b570-34ad16483039
53 "EIP-2981: NFT Royalty Standard" Zach Burks, James Morgan, Blaine Malone, James Seibel, Ethereum Improvement Proposals, September 15, 2020, https://eips.ethereum.org/EIPS/eip-2981
54 For example ERC-721 and ERC-1155 on the Ethereum blockchain.
55 "EIP-2981: NFT Royalty Standard", Zach Burks, James Morgan, Blaine Malone, James Seibel, Ethereum Improvement Proposals, September 15, 2020, https://eips.ethereum.org/EIPS/eip-2981
56 Ethereum Improvement Proposals (EIPs): proposed standards specifying new features on Ethereum.

The startup Stendhal[57] has thus developed **Collab Splitter**,[58] a web application that allows artists to create and deploy a smart contract* compatible with this Ethereum standard, in order to receive and distribute payments in crypto-assets according to customized rules.

Decentralized Science

According to the Institute of Research for Development (IRD),[59] a French public institution under the dual supervision of the Ministries of Higher Education, Research and Innovation and of Europe and Foreign Affairs, the link between the world of research and the Sustainable Development Goals is bound to grow stronger: *"While the role of certain actors in achieving the Sustainable Development Goals (States, NGOs, international organizations, etc.) may be obvious, this is not the case for research, whose role in this area is not well known. Yet research is - or will be - called upon to play a key role in achieving these goals by 2030: producing reliable knowledge and data, proposing innovative solutions, and evaluating the progress made. Scientific research and innovation have a major role to play in particular in developing countries, which are particularly vulnerable and face multiple challenges, both local and global (impacts of climate change, financial crises, pandemics, etc.)".*[60]

The world of scientific research is thus an object of experimentation for blockchain projects. Even if most of these initiatives are not very mature, a movement, that of Decentralized Science, seems to be emerging, according to Sarah Hamburg, neuroscientist and leader of the Lynx

57 "Who we are?", Stednhal, retrieved June 3, 2022, https://stendhal.ai/
58 "Split revenues from sales and royalties in a cheap, efficient and transparent way", Collab Splitter, retrieved June 21, 2022, https://collab-splitter.org/
59 "A committed science", IRD, retrieved July 21, 2022, https://www.ird.fr
60 "Research for development, 17 objectives for a sustainable future", September 15, 2020, https://www.ird.fr/la-recherche-au-service-du-developpement-17-objectifs-pour-un-futur-durable

project, to *"change the way research is funded and knowledge is shared and* (...) *transfer ownership and value away from industry intermediaries".*[61]

Decentralized Science aims to experiment with new sources of funding, peer review of scientific research, and open access to scientific publications and data while ensuring the anonymity of the individuals whose personal data is used.

As we saw in the "Health" chapter, a number of decentralized autonomous applications (DAOs*) exist, such as **Molecule**, a platform that allows scientists to share their research and present their projects in a structured way in order to connect with collaborators and funders interested in their discoveries.

VitaDAO, which presents itself as a DAO* *"for drug development governed by a decentralized community and whose main mission is the acceleration of research and development (R&D) in the field of anti-aging",*[62] relies on NFTs* that incorporate intellectual property licensing agreements.

In the area of scientific reviews, **Ants Review** denounces the fact that peer review and quality control of scientific publications is neither paid by journals nor valued by the academic community. Ants Review thus proposes *"a blockchain-based* (*Ethereum) incentive system that rewards scientists for peer-reviewing the work of other scientists and builds trust and reputation".*[63]

Some scientists also see NFTs* as a way to raise money for their research. The University of California, Berkeley, auctioned off an NFT based on the papers of cancer researcher and Nobel Prize winner James Allison for $50,000[64].

The creator of the World Wide Web, Tim Berners-Lee, auctioned off time-stamped files containing the source code of his invention in the form of an NFT* and raised $5.4 million[65]. Matt Stephenson, researcher and founder of Planck Manuscripts[66] auctioned off an NFT representing the results of an empirical study on OpenSea[67], and plans to use the funds to replicate the study more accurately.

61 "A Guide to DeSci, the Latest Web3 Movement", Sarah Hamburg, future.com, February 9, 2022, https://future.com/what-is-decentralized-science-aka-desci/
62 "We're a DAO collective funding and advancing longevity research", VitaDAO, retrieved Jun 21, 2022, https://www.vitadao.com/about
63 "Ants-Review: A Privacy-Oriented Protocol for Incentivized Open Peer Reviews on Ethereum", Bianca Trovò, Massari Nazzareno, January 22, 2021, *Euro-Par 2020: Parallel Processing Workshops*
64 "How scientists are embracing NFTs", Nicola Jones, Nature n°594, June 18, 2021, https://www.nature.com/articles/d41586-021-01642-3
65 "The World Wide Web's inventor sold its original code for $5.4 million", Oscar Holland, CNN, retrieved June 21, 2022, https://edition.cnn.com/style/article/tim-berners-lee-nft-auction
66 "Non-Fungible Incentives for open innovation", Planck Manuscripts, retrieved June 21, 2022, https://www.p1anck.com/
67 "Open Source Science Manuscript 1", Open Sea, retrieved June 21, 2022, https://opensea.io/

Planck describes itself as "*an incentive system to improve the incentives around open innovation*"[68]

In the health field, **Nebula Genomics** (see "Health" chapter), a U.S. biotech company founded in 2016, offers individuals the sequencing of their genome with encrypted data and gives their client control over who can access it. It is then possible to give access to this data to research labs to perform analyses without the risk of the participants' personal data being disclosed.

In June 2021, the journal *Nature* published an article entitled *"How are scientists embracing NFTs?"*,[69] asking whether this trend is *"a fascinating art fad, an environmental catastrophe or the future of monetized genomics?"*.[70]

While no one has an answer today, the question is at least being asked.

68 "Non-Fungible Incentives for open innovation", Planck Manuscripts, retrieved June 21, 2022, https://www.p1anck.com/
69 "How scientists are embracing NFTs is a trend of auctioning non-fungible tokens based on scientific data a fascinating art fad, an environmental disaster or the future of monetized genomics?", Nicola Jones, Nature, June 18, 2021, https://www.nature.com/articles/d41586-021-01642-3
70 *Ibid.*

ISSUES AND QUESTIONS

It took only thirty years to deeply transform the libertarian thinking of the invention of the Internet and the Web, and to make the initial dream of Norbert Wiener, J.C.R. Licklider, Robert Taylor and many others - that of creating a citizen tool of active participation and creativity multiplied by interaction - generate an unprecedented concentration of Web services by a few digital giants whose business model is based on the exploitation of individuals' personal data, the new oil of the 21st century.

Is the promise of a new decentralization of the web, brought by Web 3.0 and its services based on blockchains, just a redistribution of the cards towards new centers of power?

How can we ensure a real decentralization of services such as application and data hosting?

Our analysis shows that the initiatives in the field of media and political information have been inconclusive. Moreover, the initiatives in the field of decentralized science are still at the experimental stage.

Does the wave of NFTs* in the cultural industries augur a re-equilibration of the balance of power between artists and the intermediaries on whom they depend in their relationship with their audience? How do these projects redistribute value among the members of a community like the one supported by Hive or Steem?

Doesn't monetization and ownership of content via NFTs* make access more limited and restricted to a circle of insiders? In what way will NFTs* allow the greatest number of people to have access to art and to new sources of financing? Just some of the many questions remaining unanswered today...


ENERGY

ENERGY

Number of projects in the directory: 124

Number of active projects: 45

Name of active projects: Allinfra ; Ampere Energy ; Bitlumens ; Blok-Z ; Brooklyn Microgrid ; Clear Trace ; EcoKraft ; Electrify.Asia ; Electron ; Energy Unlocked ; Energy Web Foundation ; EnergyChain ; Enervalis ; Engie Power Corner ; Evolution Energie ; FlexiDAO ; Greeneum ; Grid Singularity ; Grid+ ; HydroCoin ; Irene Energy ; Leap ; LO3 Energy ; M-Kopa Solar ; OLI Systems ; OmegaGrid ; PowerLedger ; Powerpeers ; Prosume ; Pylon Network ; Red Grid ; Restart Energy ; Rewatt ; Share & Charge ; Solar Bankers ; SolarCoin ; SolShare ; Spectral ; Sunchain ; SunContract ; TEO : The Energy Origin ; The sun exchange ; Volt Markets ; WePower ; WPPEnergy. *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

Sustainable Development Goal (SDG) 7, in particular access to energy (target 7.1) and the promotion of renewable energy (target 7.2), is specifically aimed at solving the dual challenge of a growing population and an "electricity divide", with just under one billion people living without electricity, half of whom live in sub-Saharan Africa. Access to energy is also the pivotal point from which several other Sustainable Development Goals can be achieved, including employment (SDG 8), the fight against climate change (SDG 13) and food production (SDG 2 and 12).

By virtue of their intrinsic properties of being a peer-to-peer network and ensuring the transparency of a common registry in a secure environment, distributed registries and blockchains are finding a vast field of exploration in the energy field.

As early as 2015 the first projects emerged such as **Brooklyn Microgrid**, **Aizu Labs**, **Verv** or **Evolution Energie**, some of which have since disappeared. Others have pivoted and changed technology, such as **M-Kopa Solar**.[1]

1 Founded in Kenya in 2010 as a proprietary platform that combines GSM technology with a solar power kit to enable product financing via micro-credit for low-income customers in Kenya, and claims, by 2021, to have financed nearly "$400 million that has enabled one million customers [in Kenya] to access solar lighting, energy-efficient televisions and refrigerators, smartphones, and cash loans." About M-KOPA".M-KOPA, retrieved May 16 2022, https://m-kopa.com/

The PositiveBlockchain.io database shows some 124 blockchain projects operating in the energy sector, of which only 45 are still active in 2022.

All these projects are based on the concept of electricity tokenization. An energy production unit, be it hydro, wind or solar, is equipped with an electronic device that measures, at the source, the quantity of energy produced, represented in the form of tokens recorded in a blockchain. This "tokenized electricity" can then be traded on a peer-to-peer energy market that allows for the production, sale, purchase and consumption of green energy.

Since the energy comes from a renewable energy source, certified by a token, an energy certificate can be generated and resold as an energy commodity, either as a carbon credit for a company that wants to offset its greenhouse gas emissions, or as a certified renewable energy financing channel.

For example, since 2019, French company Ledger has been equipping wind turbines, solar panels and hydroelectric facilities of energy provider Engie with an electronic box.

This box captures a facility's electricity production data and logs it in a public blockchain to keep track of it without using the usual certification bodies such as Powernext.[2] This box is secured both from a software point of view, the private key being secured inside the box,[3] and from a hardware point of view, such as the addition of an accelerometer to detect if the box changes place and to detect any fraud attempt.

The use of blockchains in the energy domain and their representation in the form of tokens corresponds to three major interdependent use cases, which we have classified as **Energy Trade**, **Energy Certificate** and **Grid Operations**. The decentralization of voluntary carbon markets, donations of crypto-assets to environmental projects, and agroecology and reforestation projects are covered in the "Environment and Climate" chapter.

The **peer-to-peer energy market** consists of connecting local electricity producers and consumers who buy and sell electricity to each other. This is called collective self-consumption.

As Alice Zannini of Utrecht University in the Netherlands in her thesis "Blockchain technology as the digital enabler to scale up renewable energy communities and cooperatives in Spain",[4] defended

2 "Powernext, marché réglementé de l'énergie : tout comprendre", Charlotte Martin, October 4, 2021. https://opera-energie.com/powernext-comprendre/

3 "Engie et Ledger inventent un boîtier pour automatiser la collecte de données", Floriane Leclerc, November 9, 2018, https://www.usine-digitale.fr/article/blockchain-engie-et-ledger-inventent-un-boitier-pour-authentifier-les-donnees-en-entree.N767439

4 "Blockchain technology as the digital enabler to scale up renewable energy communities and cooperatives in Spain", Alice Zannini, Thesis, 2020, d'Utrecht University, https://studenttheses.uu.nl/

in 2020, notes: *"the problem is that the current energy system is designed for one-way energy flows and does not take into account the role of prosumers in creating two-way energy flows".*[5] Prosumers are energy consumers who produce and consume electricity.[6]

As a result, the European Union funded the PV-Prosumers4Grid[7] project in 2020, conceptualized in 2017, to study this trend and distinguish between three prosumer concepts: individual self-consumption; collective use of a photovoltaic installation in a given location; and neighborhood-scale energy patterns.

Renewable Energy Certificates (RECs) are a market-based instrument that certifies that the holder owns one megawatt hour (MWh) of electricity generated from a renewable energy resource.

Once the electricity supplier has injected the energy into the grid, the resulting renewable energy certificate can then be sold in the market as an energy commodity, including to other polluting entities as a carbon credit to offset their greenhouse gas emissions, or else as a channel for certified renewable energy financing.

A "decentralized Renewable Energy Certificate" (dREC) is, as **AllInfra,**[8] a startup founded in Hong Kong in 2018, explains, *"the digital representation of a renewable energy certificate whose data, recorded in a blockchain, is verifiable by anyone participating in the network".*

The advantage of such a system is that the financial vehicle, a token, makes the origin of renewable energy production much more transparent, and most importantly no longer requires any intermediary between where and when the renewable energy is generated and the creation of the digital certificate.

The ***Grid Optimization*** category, meanwhile, corresponds to blockchain projects that operate and implement a distributed electricity grid.

Notably, and as a sign of maturity, the energy field has seen a major public blockchain initiative, led by the Energy Web Foundation, which stands out from the many projects based on private blockchains.

handle/20.500.12932/36373?show=full
5 *Ibid.*
6 "La place des prosommateurs dans un réseau énergétique en pleine évolution" https://cordis.europa.eu/article/id/303126-prosumers-in-the-changing-energy-grid/fr
7 PV-Prosumers4Grid : https://www.pvp4grid.eu
8 AllInfra, retrieved June 27, 2022, https://allinfra.com/

Energy Web Foundation is a Swiss nonprofit foundation created in 2017 by the Rocky Mountain Institute[9] and Grid Singularity[10] with the goal of creating an "energy ecosystem"[11] based on the intrinsic properties of a public blockchain whose permission nodes are managed by a federation of energy companies which can apply to become permission nodes of the network.

This public blockchain with permissions*,[12] launched in 2019 and specifically designed to operate energy-related services, has seen the development of some 30 decentralized applications and smart contracts* including **Blok Z, FlexiDAO**, **Electron** and **LO3 Energy**. The Energy Web blockchain is a public, open source blockchain, derived from the Ethereum blockchain and which relies on proof-of-authority as a consensus mechanism. This allows it to "increase performance by 30 times and reduce energy consumption by two to three orders of magnitude compared to Ethereum".[13]

In addition to this major difference with Ethereum, the Energy Web Chain blockchain has also been adapted to facilitate the integration of Internet of Things* devices and connect distributed energy systems to them.

Parity Technologies and **Slock**, founded by Ethereum developers, are working with the Energy Web Foundation to improve the source code of their blockchains.

The initial design of the blockchain allows any device or user to read and write transactions, but relies on a network of authorized participants to maintain network integrity and validate transactions. In the case of the Energy Web, only authorized energy market participants, approved by the network governance model, serve as validation nodes.[14]

The choice of a public permissioned blockchain addresses the three issues identified by the consortium: being able to respond to a scale-up of the service; offering low transaction costs; and consuming little energy.

As of May 2022, 27 projects in 15 countries are deployed on the Energy Web Foundation's blockchain in four main areas: Distributed Energy Resource (DER) management; traceability; lifecycle management; and e-mobility.[15]

9 "Our Work", RMI, retrieved May 16, 2021, https://rmi.org/
10 "We Build Grid-Aware Energy Markets", Grid Singularity, retrieved May 16, 2022, https://gridsingularity.com/
11 "What is behind the EWT tokens?", TheLuWizz, Medium.com, June 26, 2021, https://medium.com/geekculture/what-is-behind-the-ewt-tokens-41b63cf8059b
12 Words marked with an asterisk refer to the glossary.
13 Energy Web Foundation: https://www.energyweb.org/
14 "Validators Visualization", Energy Web, retrieved May 16, 2022, https://validators.energyweb.org/
15 Energy Web Foundation Map: https://www.energyweb.org/project-map/

Distributed Energy Market and Distributed Energy Resources

Centralized energy production and distributed energy production/ consumption are two production models that are difficult to reconcile, because the architecture of national electrical networks has been built around a few very large production centers. This issue is not new. In February 2006, the European Commission's European Research Information Magazine No. 48 explained it in these terms:[16]

"The centralized system prevailing until today in the European electricity market is based on a pyramidal vision, essentially focused on the 'duty' of distribution in this essential energy vector. The current priority is to ensure the 'descent' of an 'electrical manna', which must first be generated upstream in gigantic production units, where large nuclear power plants predominate - with reactors delivering average powers of around 1,300 MW - or thermal power plants burning massive quantities of fossil fuels. From there, very high voltage lines run - via interconnected networks with decreasing voltages - to a myriad of consumption points spread over vast national (or cross-border) geographical areas. Although these points differ greatly depending on whether they are industrial, tertiary or individual consumers, the needs to be satisfied are united in a single entity perceived as a 'global' demand. ***Such a structure, built on gigantism, has so far proved to be an almost prohibitive obstacle to the development of renewable energies*** *which, by nature, can only supply electricity in small or very medium power ranges".*

This centralized model has not, however, prevented the progressive development of local electricity installations, whether or not they are connected to the national grid, notably driven by the production of wind energy, biomass energy, solar energy or micro-hydro power. These Distributed Energy Resources (DER) are "*electricity generation units (generally in the range of 3 kW to 50 MW) located in the electrical distribution network, at or near the end user's site",* explains Barney L. Capehart, from the University of Florida's College of Engineering.[17] These distributed energy resources, driven by the continued decline in wind and solar prices, encompass all of the techniques and technologies related to the generation, storage and distribution of electricity, including "demand-side metering" systems, which then allow the electricity generated to be sold back locally to other facilities in the same area, or to the national grid when permitted by law.

16 "Le joker de la production distribuée", RDT info, n°48, Magazine d'information sur la recherche européenne, Unité Information et Communication de la DG Recherche de la Commission européenne, February 2006, web.archive.org

17 "Distributed Energy Resources (DER)", Barney L. Capehart, PhD, CEM College of Engineering, University of Florida Updated, October 20, 2016, https://www.wbdg.org/resources/distributed-energy-resources-der

How the electricity market works in France[18]

Between 1999 and 2007, the electricity market in France was gradually opened to competition and is part of the European drive to create an "internal energy market".[19] The electricity market in France is composed of 1. electricity producers, 2. electricity network operators, and 3. electricity suppliers who operate in two different markets: the retail market, which is aimed at consumers so that they can have access to electricity; and the wholesale market, which is the market where electricity is negotiated and purchased by suppliers from producers, before it is sold on the retail market.

Since electricity cannot be stored for later use, electricity production must be matched as closely as possible to consumer demand on the retail market, and it is the said wholesale market that ensures this balance between electricity supply and demand.

The wholesale market brings together electricity producers and energy suppliers, and the traders who act as intermediaries between them. Transactions between producers and suppliers take place on several types of markets, including power exchanges, such as Epex Spot,[20] the European power exchange, and over-the-counter markets, which are either unmediated between producers and suppliers or intermediated, i.e., through a power trader.

On the wholesale market, electricity is sold according to its consumption date, i.e. either in the immediate term, so-called "spot" products, or in forward markets, allowing prices to be anticipated.

The general organization of the electricity market is therefore not designed for the end customer (the consumer in the retail market) to start producing electricity, let alone trade their excess production or reinject it into the electricity grid infrastructure.

18 Inspired by "Comment fonctionne le marché de l'électricité en France ?" publié par Hello Watt. https://www.hellowatt.fr/contrat-electricite/marche-electricite
19 "Marché intérieur de l'énergie" https://www.europarl.europa.eu/factsheets/fr/sheet/45/marche-interieur-de-l-energie
20 Epex Spot: https://www.epexspot.com/en/market-data

The value proposition of blockchain projects is twofold. The first is to be able to considerably simplify the wholesale and retail markets by measuring energy production at the source, generating financial instruments to encourage the production of green electricity (see above). The second is to adapt the electricity market to these new electricity production units, without requiring intermediaries between producers, network operators and consumers.

Distributed registries and blockchains seem to offer an ideal framework for shifting from the current energy production model, which is designed to distribute electricity in a one-way fashion, to the local level, to take into account the role of producers/consumers in the production of energy among themselves and for the national grid.

These technologies are also seen as one of the ways to realize and enhance the development of local power generation in places where the power grid simply does not exist. These technologies could also allow better valorization of primary energy sources such as solar, wind, hydro or derived energy sources (energy derived from heat produced for other purposes), by being able to tokenize the production of renewable energy.

The idea is complex to implement, however. *"If there are more and more decentralized generators connected to it, you have to ensure the stability of the power flowing, the balance between centrally generated power and the contribution of the decentralized"* warns Philipp Strauss, Dispower Coordinator at the Institut für Solare Energieversorgunstechnik at the University of Kassel in Germany.

Nine distributed energy resource management blockchain initiatives are building on the Energy Web Chain, including **FlexAlert** in California, which allows local residents to receive alerts when the power grid faces a critical need for savings, **Project EDGE** in Australia, a marketplace where grid managers can regulate the demand for and purchase of solar electricity stored in the batteries of thousands of Australian homes to balance the grid, or the **SIM-centric blockchain-enabled IoT**, led by telecom operator Vodafone, which combines SIM-centric blockchain technology with Vodafone Business' IoT connectivity to securely and efficiently integrate renewable and distributed assets such as wind turbines, batteries, heat pumps and solar panels into energy networks.

Electron, a London-based startup founded in 2015, is also developing a digital infrastructure along these lines, likewise based on the Energy Web Chain, which is aimed at power grid operators, financial markets, and electricity consumers, to manage distributed power generation with local marketplaces,

allowing the power grid operator in particular to *"manage the challenges of intermittency, congestion and power quality presented by the growing penetration of renewable energy".*[21]

Electron has deployed eight grid optimization projects in four countries since 2015. In England, a two-year pilot project, called TraDER, was developed in Orkney, a subarctic archipelago north of Scotland that has seventy-seven islands, only sixteen of which are inhabited.

The £3 million funded project, conducted in partnership with EDF, Scottish and Southern Electricity Networks, Kaluza (OVO Group) and others, ran from July 2019 to March 2021.

It involved creating a local energy market that was both physical and real-time: *"Electron's market platform connected renewable energy producers, subject to power constraints and outages, to flexible local energy assets capable of absorbing excess energy, allowing more wind generation to be exported and consumed*"[22] explains the company's website.

This pilot contributed to the development of their decentralized demand response energy platform, Flexibility Marketplace, which aims to dynamically manage, in near real time, the balancing of markets between the needs of local electricity operators and the needs of national operators.

Produce clean electricity locally, consume it, sell the surplus around you or, if there is a shortage, buy it from around you. This is the promise of collective self-consumption of renewable electricity backed by distributed blockchain-type registers.

All of this is done automatically, with the guarantee that all transactions - electricity production, sale and purchase - will be recorded in a distributed and unforgeable register.

Collective self-consumption meets the energy challenge of reducing electricity consumption from centralized and fossil sources and sharing the energy surplus of "clean" installations within a territory and its homes, businesses, charging stations, etc...

21 "What blockchain can do for power grids?", Magda Foti, Manolis Vavalis, Blockchain: Research and Applications, Volume 2, Issue 1, 2021, https://doi.org/10.1016/j.bcra.2021.100008.
22 "Blockchain energy trading live in Scotland's Orkney Islands", Jonathan Spencer Jones, May 20, 2020, https://www.ledgerinsights.com/blockchain-energy-trading-live-scotland-orkney-islands/

Distributed Renewable Energy Certificates

In France, Energy Savings Certificates (CEE) were set up in 2006[23] and imposed by the public authorities on energy suppliers, known as "obligated parties", to accelerate their energy transition by reducing their energy consumption and encouraging their customers to do the same. Large companies, particularly in the industrial sector, called "non-obligated", can also obtain CEEs to sell on a financial market. As explained by Certinergy, a subsidiary of Engie, specializing in CEEs, *"the entity that has invested in equipment or a site to improve its energy performance is instantly rewarded for its efforts by receiving money from the sale of its CEEs".*[24]

The price per kWh is administered by Powernext[25] in a centralized registry called Emmy.[26] These French energy saving certificates are related to the European Renewable Energy Certificate System (RECS), which is responsible for European Energy Certificates (European Energy Certificate System or EECS).[27]

The D-REC (Decentralized Renewable Energy Certificate) private sector-led[28] multi-stakeholder initiative aims to implement, test, and experiment with new financial mechanisms to incentivize and meet the demand of large corporations to invest in renewable energy development in developing and emerging markets, particularly in Africa.

A first phase of the project aims, in partnership with the United Nations Development Program (UNDP), to support the electrification of 1,000 hospitals and clinics in Africa,[29] with $45 million in capital expenditure already secured by 2021.[30]

Thus, a D-REC, being the digital representation of a renewable energy certificate, certified via a blockchain, becomes a financial instrument directly accessible to companies seeking to acquire energy saving certificates.

23 French Law n° 2005-781of July 13 2005 fixing orientations of energetic policy https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000813253/
24 "Certificats d'Economies d'Energie (CEE ou C2E) : le guide complet" Caroline Dusanter, June 6, 2022. https://opera-energie.com/certificats-economies-energie-cee/
25 European Energy Exchange https://www.powernext.com/fr/fr
26 Registre National des Certificats d'Economies d'Energie https://www.emmy.fr/public/accueil
27 Les certificats d'électricité verte (RECS) https://www.futura-sciences.com/planete/questions-reponses/energie-renouvelable-certificats-electricite-verte-recs-1430/
28 D-REC https://www.d-recs.energy/about-us/
29 "Blockchain energy trading live in Scotland's Orkney Islands", Jonathan Spencer Jones, May 20, 2020 https://www.ledgerinsights.com/blockchain-energy-trading-live-scotland-orkney-islands/ https://sustainablebrands.com/read/cleantech/from-silicon-valley-to-rural-africa-boosting-energy-access-with-the-d-rec-initiative
30 "About us", The D-REC Initiative, retrieved May 16, 2022, https://www.d-recs.energy/wp-content/uploads/2021/12/Overview-of-the-D-REC-Initiative.pdf

An experiment was established in Rwanda in 2020. Photovoltaic panels, connected to measuring devices linked to the Internet of Things (IoT) are deployed in rural areas off-grid, on small buildings. Solar energy production data is recorded in a blockchain and renewable energy certificates are generated in the form of D-REC tokens, which are then purchased on financial markets by both obligated (electricity supplier) and non-obligated (large company) participants.

There is no intermediary between the location of the electricity production, which can be a solar home system, a commercial rooftop system, a community mini-grid or a micro-grid, the issuance of the distributed renewable energy certificates, or the market on which these certificates are traded, which opens up huge prospects for securing the financing of these renewable energies.

Specifically, a project developer installs a distributed renewable energy system, such as a home solar system, a commercial rooftop system, a community mini-grid, or a campus microgrid in a specific area. As electricity is generated, the data is transmitted to a D-REC monitoring and tracking platform whose role is to aggregate data from multiple renewable energy systems and make them compliant with international standards organization protocols.

A company then buys these D-RECs and the proceeds of the sale go back to the operators who have implemented the renewable energy system.

"More and more companies are strengthening their sustainability commitments by purchasing clean energy. Some are increasingly looking to push their commitment to renewable energy into emerging markets where they have a direct footprint, or indirectly through their supply chain partners. At the same time, there is an acute need for clean, reliable energy for things like health clinics or SMEs in off-grid communities in many of these same countries"[31] says Patrick Bürgi, chief innovation officer and co-founder of South Pole, one of the general secretaries of the D-REC initiative.

"The D-REC initiative uses a proven, market-based instrument to reconcile these needs in a way that can have a positive impact on a large scale". With support from the United Nations Development Program (UNDP), D-RECs channel funding directly from large companies to operational projects, rather than to intermediaries who make the verification of these energy certificates opaque and complex.

FlexiDAO, a startup created in November 2017, based in Barcelona, Spain and headquartered in Amsterdam, The Netherlands, is also part of this "electricity tokenization" movement by which each

31 "UNDP Partners with D-REC Initiative to Scale Up Energy Access Through Innovative Investment Models", UNDP, August 3, 2021, https://www.undp.org/press-releases/undp-partners-d-rec-initiative-scale-energy-access-through-innovative-investment

unit of electricity becomes a digital asset generating an energy certificate, whose issuance and transfer are based on cryptographic proof.

Built on the Energy Web blockchain, FlexiDAO's data streams are organized into five categories, explains Accornero, FlexiDAO's co-founder and CEO:
1. Private metadata of assets and consumers stored in a retailer database. The hashes are used as secure proof of on-chain* data for validation of off-chain* data.
2. Contract data that links anonymous identities (users, assets, organizations, operators, energy meters, etc.) that define and automate contractual relationships between all parties.
3. Meter data: accumulated and time-stamped active energy (both consumed and produced), attributed to an anonymous identity.
4. Certificate transaction data: data certificate exchange between anonymous identities (including the type of certificate, such as the certificate of origin of onshore wind farms) and
5. Certificate request data: The certificate request data describes by which anonymous identity and for which period of time the certificate was used/consumed. FlexiDAO thus forms the application layer, in the form of simple APIs (application programming interfaces), of a system integrating disparate data made possible by the use of a common registry.

Since 2017, FlexiDAO has developed numerous projects with Eneco, Acciona, Microsoft, Total or even Google. The most recent, in 2022, brought together FlexiDAO and Acciona Energia, a Madrid-based subsidiary of Acciona, a Spanish company developing renewable energy projects that is notably implementing large-scale green hydrogen projects.

FlexiDAO has developed an Energy Web blockchain-based platform for Acciona that guarantees the renewable origin of green hydrogen and also allows customers to verify the transportation and delivery process of this type of clean energy. The platform, called GreenH2chain, has been implemented as part of the Power to Green Hydrogen[32] project, aimed at creating a green ecosystem on the island of Mallorca in Spain. This allows consumers of renewable hydrogen to *"quantify, record and monitor the decarbonization process of their own energy supply and (...) have all the detailed information about the hydrogen consumption itself, as well as data to calculate the carbon dioxide emissions that consumers avoid by using this type of green energy".*[33]

32 GREEN HYSLAND aims to deploy a fully functional hydrogen (H2) ecosystem on the island of Mallorca, Spain, making the island the first H2 center in Southern Europe. This will be achieved by producing green hydrogen from solar energy and delivering it to end-users such as the island's tourism, transportation, industrial and energy sectors, including injection into the gas grid for green heat and local electricity end-use. "About Greenhysland", Green Hysland, retrieved May 16 2021, https://greenhysland.eu/about-green-hysland/
33 "Acciona Energia. Case study.", GreenH2Chain, retrieved May 16, 2022, https://www.flexidao.com/case-studies/green-h2-chain-by-acciona

Peer-to-Peer (P2P) Energy Trading Microgrids

Blockchains and distributed ledger technologies also enable decentralized energy systems and microgrids where producers/consumers interact in peer-to-peer energy markets.

Collective self-consumption consists of locally producing clean electricity, consuming it, selling the surplus around you or, if there is a shortage, buying it around you, with the guarantee that all transactions, electricity production, sale and purchase, will be recorded in a distributed and unforgeable registry.

The first proofs of concept were carried out more than ten years ago, with, in particular, the highly publicized "Brooklyn Microgrid" project led by Siemens, LO3Energy and Consensys in 2011, deployed at the scale of a New York City neighborhood in the United States. Microgrids are *"small-scale power systems designed to provide a reliable and high-quality supply of electricity to a small number of consumers. They aggregate multiple local and distributed generation facilities (...), consumer facilities, storage facilities, and monitoring and demand management tools. They can be connected directly to the distribution network or operate in island mode and can be applied to different scales of territory (building, neighborhood, industrial or small business zone, village, etc.)".*[34]

This peer-to-peer energy supply in micro-grids is also aimed at populations disconnected from any electrical grid. These initiatives, such as SunChain, SOLshare, Engie Power Corner and Power Ledger, use solar home systems (SHS) and mini-grids to monitor electricity production and consumption at the local level.

Established as a subsidiary of the German consulting firm MicroEnergy International GmbH (MEI), **SOLshare** was founded in 2014 in Dhaka, Bangladesh. Its core business is *"the design, manufacturing, management and sales of an innovative charge controller for Solar Homes Systems (SHS) that manages the interconnection between multiple users to a decentralized low-voltage DC microgrid and facilitates electricity trading for households and small businesses in densely populated off-grid villages".*[35]

SOLshare enables the implementation of distributed and dynamic micro-grids that provide solar energy to a local population far from any electrical grid. People with photovoltaic panels on their homes produce electricity for their own use and can also sell their excess electricity around them according to the network built between them.

"Through our solutions, rural communities can trade solar power, reduce their greenhouse gas emissions by 30% and

34 Commission de régulation de l'énergie, French independent administrative authority, created on March 24, 2000.
35 "Home", SOLshare, retrieved May 16 2022, me-solshare.com

Solar Homes Systems - SolShare
Source : SolShare, *https://www.youtube.com/channel/UCTnIGAHPh93AX69NpNbZfVw*

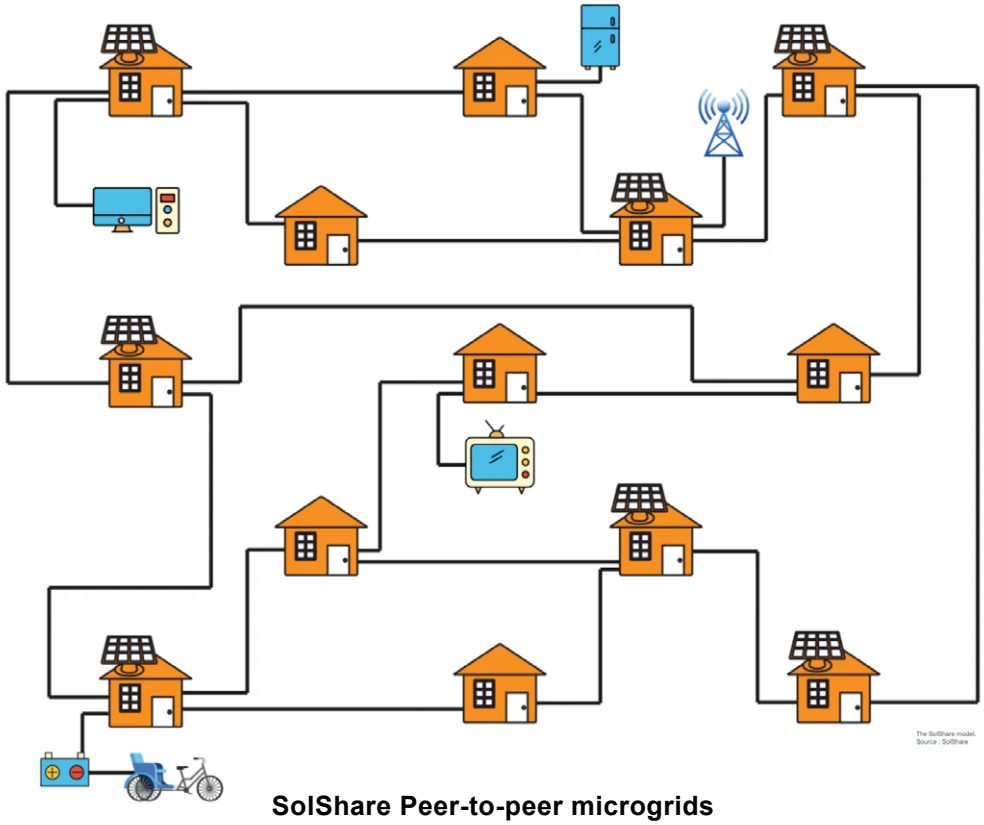
increase their household income by 25%, while e-rickshaw drivers get better charging and profit opportunities". In November 2021, SOLshare connected a distributed power system to the national grid for the first time.

ENGIE PowerCorner, incubated in 2015 within the ENGIE Group, commissioned in March 2016 PowerCorner, a first 16 kW microgrid in Ketumbeine, a remote village in northern Tanzania, providing power to some 120 local homes and businesses as well as public services including a rural health center and two schools. By 2020, ENGIE PowerCorner had 13 mini-grids in operation in two countries, Tanzania and Zambia, serving 15,000 beneficiaries, and was expected to expand into Uganda, Benin and Nigeria during 2021.

The Engie Group, an early supporter of the Energy Web Chain, announced in July 2021 that it was developing a participatory finance platform that will allow micro-investors to finance the installation of clean energy assets by staking* Energy Web Tokens (EWTs), the native token of the Energy Web public blockchain, in exchange for a fixed interest rate, similar to what the Sun Exchange platform in South Africa is already doing (see "Peer-to-peer Electronic Cash System and programmable money" chapter).

Power Ledger, founded in 2017 in Australia, raised $26 million in an ICO* to launch a solution to create a peer-to-peer solar energy exchange network to *"track, validate and provide traceability of every solar energy transaction in near-real time"*[36] explains Jemma Green, co-founder of Power Ledger.

36 Cofounder of blockchain-based solar power company explains what the technology means to the future of energy", Michael O'Neill, Business Insider, April 14, 2021, businessinsider.com



SolShare Peer-to-peer microgrids
Source : SolShare, https://me-solshare.com/

This peer-to-peer solar energy marketplace platform allows consumers to sell their electricity surplus to other commercial or residential users.

The company has deployed its platform to some 30 customers across Australia, Austria, France, Japan, India, Malaysia, Thailand and the United States.

In 2021, Power Ledger partnered in India with India Smart Grid Forum (ISGF) and Tata Power-DDL to deploy a pilot in North Delhi involving 65 producers/consumers with 75 consumer sites in the capital representing 140 buildings.

The platform enables peer-to-peer trading of solar energy from PV systems larger than 2 MW.

From a technical perspective Power Ledger first developed EcoChain™, a private blockchain based on Proof-of-Stake (PoS) to test several pilots between 2016 and 2017. In 2017, the platform was developed on a no-cost Ethereum Consortium Proof-of-Authority (PoA) network, modified for business purposes.

In July 2021, Power Ledger announced[37] it was developing a modified permissioned blockchain based on the **Solana** blockchain that would, according

37 "Power Ledger launches next generation blockchain, moves away from Ethereum", PowerLedger, Medium, July 12, 2021, medium.com

to John Bulich, co-founder and CTO of Powerledger, *"enable throughput of 50,000 transactions per second and scale to the services Power Ledger deploys: peer-to-peer, flexibility services, energy traceability, and certificate exchange applications".*[38]

In addition to offering a higher number of transactions per second, the choice to rely on the Solana blockchain is explained by the fact that it allows the company to move from an energy-intensive proof-of-work consensus mechanism to a dual Proof-of-History and Proof-of-Stake consensus mechanism more in line with Power Ledger's business.

Sunchain, a spin-off[39] of the Tecsol engineering firm founded in France in 2016, has developed several collective self-consumption installations based on a blockchain developed on Hyperledger, the most recent of which, Smart Lou Quila, was launched in March 2021 in Cailar, Gard, France.

In partnership with Enedis and 100% renewable energy provider Planète OUI, the initiative includes a six-home housing development and a sports facility, which share electricity generated by photovoltaic panels on the roofs of the homes and the municipal stadium, as well as three stationary storage batteries and an electric vehicle charging system.

Peer-to-peer (P2P) electricity trading is therefore a model based on an interconnected platform, which serves as an online marketplace where consumers and producers exchange (i.e. buy and sell) electricity directly, without the use of an intermediary.

38 "Blockchain FAQs", Power Ledger, September 2, 2021, Medium, ·https://medium.com/power-ledger/blockchain-faqs-3549a9bdeb6a

39 A spin-off is the creation of a new company within the framework of a demerger of a branch of activity of an existing company, consisting of the distribution in the form of dividends to shareholders of the shares of the subsidiary in exchange for the original shares of the parent company. https://www.mazars.fr/Accueil/Services/Financial-Advisory/Glossaire-Definition/S/Spin-off

In Africa, biomass and hydropower resources are more abundant in the humid southern and central regions of the continent, and wind power is very present in the eastern and northern regions of the continent. In contrast, the sun is present everywhere. Despite this, the continent, which has the largest solar resource in the world, has installed only 5 gigawatts of solar photovoltaic energy, less than 1% of the global total. Yet in sub-Saharan Africa, only 28% of health facilities have reliable electricity, two-thirds of schools have no reliable electricity, and distance learning is unimaginable.

The biggest barrier to solar deployment in Africa is the lack of funding for companies and organizations.

With more than 300 days of sunshine per year and falling technology costs, the International Energy Agency predicts that by 2040, solar PV will overtake hydropower and natural gas in terms of installed capacity to become the continent's leading source of electricity (International Energy Agency 2019). Mini-grids could play a critical role in providing electricity to rural communities and local businesses.

The **Sun Exchange** platform, founded in South Africa in November 2015 by Abe Cambridge, is a microleasing marketplace that connects investors, individuals, and businesses with beneficiaries of solar installations in rural areas.

The Sun Exchange platform allows anyone with an internet connection to buy solar panel cells online and lease them to businesses, hospitals, schools and other organizations based in Africa, with the promise of a 10% return on a 20-year contract.

The Sun Exchange platform organizes the process of collecting and distributing monthly rents through Bitcoin or local currency. The platform uses the Bitcoin blockchain for cross-border payments so that there is no middleman between the beneficiaries of the facility who pay for their electricity and the investors who participated in the purchase of the solar panels.

Between January and November 2015, The Sun Exchange installed the prototype of the first solar power plant at a school in the Cape Town area, funded entirely by individuals in crypto assets. As of February 2022, more than 50 solar installations have been funded by investors in 183 countries around the world with a total electrical capacity of 10.9 megawatts.

How does The Sun Exchange implement a local solar project?

A team of engineers from The Sun Exchange works with local construction companies to evaluate the technical and economic feasibility as well as the social and environmental impact of a solar project. Once the project is ready for funding, it is posted on the crowdfunding platform, where anyone can sign up and buy solar cells at a cost of 50 South African rand ($4) per cell. Once all the solar cells are sold, the local partner takes care of the construction work, which takes an average of four to six weeks.

The solar panels are connected to The Sun Exchange platform through smart contracts* using Internet of Things (IoT) sensors. Once the solar installations are operational, the beneficiary pays to consume the electricity produced by the cells, and the owners of the solar panel receive the amount corresponding to their investment each month in the form of rent, net of insurance and service fees, paid in local currency or Bitcoin.

Beneficiaries include schools, retirement homes, small and medium-sized businesses, nature parks, non-profits and other organizations that cannot afford the initial investment of a solar installation. With The Sun Exchange's solar installations, these organizations have reduced their energy costs by 20-30% and have been able to redirect those funds to their core offerings, including providing quality education for children, positive living environments for elderly residents, and care for vulnerable wildlife. In 2019, projects in schools and nursing homes benefited some 5,500 learners and 150 seniors.

For The Sun Exchange platform to endure, the cost of solar photovoltaic electricity must be lower than electricity generated from fossil fuels or carbon-intensive energy. Lower technology costs have led to a drastic drop in the price of solar electricity.

According to BloombergNEF's[40] 2019 New Energy Outlook report, the cost of solar modules has dropped 89 percent since 2010 and will drop another 34 percent by 2030.

In addition, blockchain and crypto-assets are making impactful financing possible through frictionless cross-border payments, that bypass costly financial intermediaries between micro-investors and solar project beneficiaries, through smart contracts*.

40 "BloombergNEF New Energy Outlook 2019" https://about.bnef.com/new-energy-outlook/

ISSUES AND QUESTIONS

Because the diverse experiments implementing blockchains in the energy sector began more than a decade ago, the sector seems to be maturing faster than others.

The initiative led by the Energy Web Foundation shows the value of a public permissioned blockchain from which other companies, startups or governments innovate by relying on a common registry and infrastructure.

Whether it is to keep records of energy supply, metering, or billing transactions, several other applications offer interesting prospects, notably in the field of energy certificates, guarantees of origin or emission quotas. However, the development of these initiatives is still facing major challenges.

The electricity sector involves critical infrastructure that must be operated and maintained by one or more operators.

Nevertheless, the disintermediation made possible by the development of blockchain projects shows that *"while some intermediaries such as trading platforms, traders, banks or energy companies might still be necessary, their role would at least be considerably reduced"*, as explained in the 2016 report "Blockchain - an opportunity for energy producers and consumers?" published by PWC.[1]

Can we anticipate a rise in the number of users of peer-to-peer energy trading, for which blockchains serve as a registry to record the production and consumption of electricity? Will blockchains be able to handle hundreds of thousands or even millions of transactions? What will happen if the grid goes down? Who will be responsible and who will pay for any repair costs, whether hardware or software? Isn't there a risk of an "electrical divide" between individuals who are able to equip themselves and become energy producers, and those who will remain *de facto* consumers?

Nevertheless, blockchain initiatives are providing innovative responses to these problems, as illustrated by the Sun Exchange platform and SolShare.

1 "Blockchain – an opportunity for energy producers and consumers?", PWC, 2016. https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf

How will the traditional operators of the electricity networks be able to adapt and balance the production of energy according to the supply and demand generated by these peripheral networks?

Furthermore, there is the question of the confidentiality of the data exchanged on these platforms. In the market of prosumers, who are not only producers but also consumers of electricity, how can we ensure that transactions are both certified and respect the confidentiality of personal data? There is additionally the question of how to manage disputes due to the absence of intermediaries.

Finally, another key issue is the evolution of the regulatory framework that would allow mini-grids to be deployed more widely across the country, permitting better coordination and greater efficiency in the exchange and sharing of data between the national grid and these mini-grids.

GOVERNMENT & DEMOCRACY

GOVERNMENT & DEMOCRACY

by **Pierre Noro**, Researcher, lecturer at SciencesPo Paris and at the Learning Planet Institute of the Université Paris Cité, COO of Pebble.vote

Number of projects in the directory: 78

Number of active projects: 34

Name of active projects: Aragon ; Bitland ; Blockademia ; Callisto ; Chromaway ; Civic Ledger ; DAOhaus ; DAOstack ; Democracy Earth ; District0x ; EBSI ; Electis ; FlexFinTx ; Followmyvote ; Geon Network ; Gitcoin ; GivEth ; Gmerits ; Horizen ; Horizon State ; Originalmy ; OS City ; Polys ; Possible Today Foundation ; Procivis ; Singapore Smart Nation Initiative ; Smart Certificate ; Smart Dubai ; SourceCred ; Tellor ; The Bounties Network ; The Commons Stack ; TruBudget ; Voatz ; *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

How can a resolutely anarchist, libertarian technology, with an "anti-state" philosophy, be presented as an opportunity for the renovation of our democratic systems and public administrations, at the local, national and international levels?

There is a surprising porosity, an unexpected dialogue between blockchain ecosystems and public institutions. The answers provided by the former, in the face of systemic flaws and abuses by trusted third parties, are now an essential source of inspiration for public innovation.

Blockchain technologies in general and decentralized governance systems in particular question the place of trust in the organization of our societies.

Far from the fantasy of engaging in "trustless" systems, which would rely exclusively on free market mechanics, the use of decentralized ledgers and of networks conceived to incentivize open participation questions the conditions of trust in an increasingly transborder, digital society, with more horizontal and polycentric forms of governance[1].

1 Primavera de Filippi, Morshed Mannan, Wessel Reijers. Blockchain as a confidence machine: The problem of trust & challenges of governance. Technology in Society, Elsevier, 2020, https://hal.archives-ouvertes.fr/hal-03098449

In the context of the rise to power of new political leaders elected with populist and illiberal platforms in a growing number of states, including the ones with the longest republican and democratic traditions, and while international polls indicate a deep and global crisis in public trust and people's attachment to democracy, the experiments presented here, whether they achieved a real positive social impact or have remained at the project stage, provide us with valuable lessons on the essential conditions for successful and innovative democratic governance mechanisms: openness, transparency, and decentralization.

Bitcoin beyond BTC, an ideology and an alternative governance

By inscribing in the "*genesis block*", the very first block of the Bitcoin blockchain, a reference to the January 3, 2009 headline of *The Times*, Satoshi Nakamoto is not only cementing the foundation of his famous creation. He explicitly claims, from the very beginning of Bitcoin, its revolutionary, alternative, if not anarchist nature:

"The Times 03/Jan/2009 Chancellor on brink of second bailout for banks[2]."

In a brief message, Satoshi Nakamoto reaffirms the ideology of the cypherpunks[3] and the need to break free from a financial and monetary system plagued by a deep crisis. In the eyes of the small community that is gathering around Bitcoin and the previous experiments that led to the advent of the first major cryptoasset, the States and their centralized power are just as guilty as the financial institutions for the 2008 crisis. The "*bailouts*[4]" carried out with large amounts of public money are both examples of the arbitrary nature of sovereign monetary policies and symptoms of an insufficiently transparent, open and decentralized financial system.

Blockchain technologies are enabling alternatives to sovereign currencies, but also to centralized organizations, whether private or State-based. Bitcoin is quickly proving that a distributed ledger within an open, peer-to-peer, *open source* network can become a public digital infrastructure which allows its pseudonymous users to synchronously and securely store and share identical and immutable information, whether financial or non-financial. Blockchain technologies do not only challenge the State's monopoly on sovereign money: they question the role and necessity of any trusted third party, of any intermediary and of any centralized and vertical organization.

2 "The Times 03/Jan/2009 La chancelière au bord d'un second plan de sauvetage des banques".
3 Portmanteau word constructed from "cipher", a type of encryption, and "punk". It refers to people who advocate the widespread use of strong cryptography and privacy-enhancing technologies as a path to social and political change.
4 "Bailout" means the granting of financial assistance to a company or country to prevent it from going bankrupt or insolvent.

These values of openness, transparency and horizontality at the heart of Bitcoin are also baked in its governance. The Bitcoin software is *open source.* It allows anyone to access the registry and become a validator (see Introduction). The governance of the network is initially informal, with the community organizing itself around forums and email loops before several *core developers* (Amir Taaki, Luke Dashjr and Pieter Wuille in particular) standardize the Bitcoin Improvement Proposals[5] (BIP) system in the summer of 2011.

Adopting the collaborative tools used in other *open source* communities as a model, *Bitcoin Improvement Proposals* become the format for anyone to suggest an update to Bitcoin's code. Once presented to the community, *via* the Bitcoin open *mailing list*, and discussed a first time to ensure their relevance, the BIPs with enough community endorsement are submitted to the miners' vote[6], who indicate in each validated block their support for one or more BIPs.

The voting power is distributed in proportion to the computing power of each miner, since the probability of having one's vote taken into account is the same as the probability of producing the next valid block.

If during a certain period more than 75% or 95% of the blocks contain a favorable signal, the relevant BIP is implemented.

The Bitcoin blockchain thus operates not only as an infrastructure for the peer-to-peer creation and exchange of its own cryptoasset, Bitcoin, but also as an integrated voting and coordination tool to support its own decentralized governance.

Nevertheless, this governance model involving the Bitcoin community as a whole on the one hand and the miners on the other has shown several limitations. Despite its open, participatory and transparent structure, Bitcoin's governance leans more towards meritocracy -if not aristocracy- than towards democracy: the informal community discussions preceding the submission of BIPs, although open to everyone, give a major role to the most active and influential *core developers*.

More importantly, the adoption of certain BIPs deemed by the community as critical to Bitcoin's long-term technical evolution and adoption sometimes clashes with the miners' interests and profit maximization.

5 Bitcoin Improvement Proposals : un document conçu pour proposer et introduire des fonctionnalités ou des informations aux utilisateurs de l'infrastructure Bitcoin.
6 This is, as Peter Wuille points out, a simplification: miners do not vote but signal their support for BIPs that they are willing to implement. Any Bitcoin user operating a *full node* can install a version of the program that implements any update they think is relevant, at the risk that their program will no longer recognize blocks validated by miners running a non-compatible version of Bitcoin. https://bitcoin.stackexchange.com/questions/97043/is-there-an-active-list-of-bips-currently-open-for-voting

This divergence reached a paramount during the summer of 2017, when several BIPs competed to solve Bitcoin's scalability[7] issue.

Faced with a community demanding the implementation of some of these updates to unclog the network and increase its capacity, certain "mining *pools*"* considerably and intentionally slowed down the adoption of the BIPs, as some of them, among other reasons, feared to lose part of their revenue[8].

The differences between the *core developers* and the miners over the scalability issues of Bitcoin also caused many *hard forks** giving rise to a bunch of *altcoins*,* each of them copying Bitcoin's code and history, while implementing their own mix of modifications to their source code.

This is another key characteristic of decentralized governance already demonstrated by Bitcoin: the *open source* nature of blockchain technologies allows any user supporting a minority proposal on a protocol to create their own modified version of an existing blockchain protocol if they are dissatisfied with the current consensus. Since the ledger, the data recorded in the source blockchain, is replicated in the new one at the time of the *hard fork*, users holding assets before the schism will also hold the same amount in the new assets created with the new blockchain. It is then finally up to the community to settle the case and opt to use one blockchain, the other or even both.

The first uses: blockchains as substitutes for trusted third parties

During the early 2010s, Bitcoin was rapidly demonstrating its ability to serve as a decentralized, secure and immutable registry for financial and non-financial information, and many pioneering experiments started using this feature to "notarize" documents.

Entrepreneurs developed projects and standards where a blockchain would be used to anchor unique digital proofs of existence of documents concerning land ownership, proof of identity, certificates and diplomas (see in particular the Chapters "Identity and Ownership" and "Education and Employment").

These use cases therefore offered to replace traditional trusted third parties with decentralized and open ledgers. Their ambition was to do away with States, public authorities and institutions or private intermediaries whose only mission was to accumulate the information generated by a whole ecosystem of actors, then to act as the sole repositories of certified information.

7 *Scalability* refers to the ability of an IT product, architecture or service to adapt to changes in demand while maintaining its fundamental functionalities.
8 Some miners, at least in the short term, seem to have believed that they would benefit more from the increased transaction fees caused by the blockchain's saturation than from the increase of the total number of transactions.

The use of a blockchain enables the anchoring of unique cryptographic proofs in a data structure publicly accessible, where anyone can verify the authenticity of a declaration or a document in their possession, guaranteeing the identity of the certifier and its timestamp.

Users driven by the same libertarian or crypto-anarchist ideologies at the heart of Bitcoin initially carried out these emerging use cases.

Naturally, they first targeted sectors where trust was low and the acquisition of information costly: complex environments involving a very large number of actors (supply chain tracking, international trading, speciality goods traceability...), trusted third parties that were technically deficient, fraudulent or located in jurisdictions suffering from political instability, authoritarian or illiberal power and/or high levels of corruption (such as Bitland in Ghana and Honduras or BenBen in Ghana - see chapter "Identity and Ownership"), but also illiquid markets where intermediaries used their informational rent to erect barriers to access to essential information (e.g. intellectual property market, digital identity…).

Blockchains at the service of trusted third parties

However, these use cases only really caught the public eye with experiments undertaken by traditional trusted third parties, notably public institutions. Although this might appear as a paradox, it is probably not as surprising as it seems. Institutions that were able to overcome the initial fear induced by the ideology at the heart of Bitcoin and to surround themselves with the skills required to develop pilot projects found in blockchain technologies a godsend for demonstrating their ability to innovate and to modernize their processes at a time when public innovation and digitization was at the centre of the public debate.

Although blockchain technologies facilitate the creation and operation of open, immutable ledgers, they remain "*garbage in, garbage out*" systems[9]: the technology itself cannot guarantee by itself the validity and truthfulness of the recorded information.

Far from meaning the end of all intermediaries, blockchain technologies therefore have an essential need for trusted third parties to import authentic information that is external to the data generated *on-chain**. With responsibilities similar to *oracles**, trusted third parties can seize the opportunities offered by blockchain technologies and become providers of qualified data

9 Data bias, or GIGO (*Gargage In, Garbage Out*), refers to the inclusion as input in a process of erroneous or biased information -no matter how consistent or useful they may seem- that will eventually lead to inaccurate results.

they can authenticate, by signing the anchors and putting their reputation on the line in order to generate trust around certified data.

Experiments to use a blockchain as a transparent, immutable and secure infrastructure for recording and accessing public data are extremely numerous and vary in complexity.

The State of Geneva used Ethereum to issue, in 2017, certificates for legal extracts of its commercial register[10]. In March 2018, the Chilean Comisión Nacional de Energía launched its "Energia Abierta" (Open Energy) portal, also set up on Ethereum, to anchor the public data pertaining to the power grid[11].

In the same year, several Indian local governments, including in West Bengal, announced plans to use a blockchain to secure birth certificates [12] [13], and in January 2021, one of New Delhi's local authorities considered following their lead, recording proofs of its own birth and death certificates[14].

The company **OSCity**[15] is one of the pioneers in modernizing public services in Central and South America. In partnership with Unicef Innovate and the Open Government Partnership, the Mexican company designs experimental systems harnessing blockchain technologies to modernize various public services. They notably collaborated with local governments in Argentina (certification of public lottery results in the province of Rio Negro, public funding and grants for culture in Bahía Blanca), Costa Rica (attribution of alcohol distribution licenses in the localities of Quepos and Grecia), Brazil (certification of public transportation data in the city of Teresina), and Mexico (certification of digital licenses for alcohol distribution and building permits in the municipality of San Nicolás).

Building on this track record, the company is now working on the integration of an Ethereum-based platform which combines digital identity, certificate issuance and *smart city* tools.

10 "Rapport d'expérimentation Blockchain" City of Geneva, accessed July 6, 2022, in French, https://www.ge.ch/document/rapport-experimentation-blockchain
11 "Blockchain as an Information System in Chile: The Case of Open Energy Project - Chilean's Ministry of Energy", Stefania Pareti, Ignacia Núñez, Revista Ibérica de Sistemas e Tecnologias de Informação; Lousada N° E39, (Jan 2021): 554-568.
12 "A 1st in Bengal, baby gets blockchained birth certificate", Udit Prasanna Mukherji, Suman Chakraborti, Times of India, December 20, 2018, https://timesofindia.indiatimes.com/india/a-1st-in-bengal-baby-gets-blockchained-birth-certificate/articleshow/67170551.cms
13 "Indian State Government Will Issue Birth Certificates on a Blockchain", NCC, Oct 2 2020, https://www.ccn.com/indian-state-government-will-issue-birth-certificates-on-a-blockchain/
14 Computer No.: 65981 Information technology department New Delhi municipal council, Palika Kendra: new delhi no. d-dfa/ January 25, 2021, https://www.medianama.com/wp-content/uploads/2021/06/New-Delhi-Blockchain.pdf
15 "About", OS City, retrieved July 6, 2022, https://www.os.city/

These use cases proved that trusted third parties, in particular public authorities, can use blockchain technologies to ensure more secure and transparent access to public data and to facilitate the issuance and verification of official documents.

Since these experiments may limit the risks of fraud, fight against against corruption, facilitate administrative procedures and improve overall transparency in the public sector, they are in line with some of the sustainable development goals (SDG) established by the UN, in particular goals n°11 - Sustainable Cities and Communities and n°16 - Peace, Justice and Effective Institutions[16].

Although based on a fairly simple use case, such blockchain-based public data registries are still relevant to this day, as evidenced, during the Covid pandemic, by the signature of a collaboration agreement between Mexican state of Quintana Roo's Public Institute of Innovation and Technology and the startup GenoBank.io to certify the authenticity of COVID test results.

According to the COMED (Mexican Council of Medical Diagnostic Companies), 20% of which are said to be falsified at the national level[17]. Born in response to a health scandal caused by the infection of several Argentine exchange students in the Mexican state after they reportedly tested negative in a laboratory operating without official authorization, this announcement promised a simple and rapid verification, including internationally, respectful of users' personal data.

Nevertheless, this tool, initially planned to be deployed on the Avalanche blockchain[18], seems to have been discontinued, and this has probably something to do with the setbacks of another blockchain project carried by the Quintana Roo Congress. Indeed, the local parliament has decided not to renew its partnership with this "third generation" blockchain for archiving legislative documents on Avalanche, after seven months of use[19].

The 600,000 Mexican pesos (nearly 26,000 euros) contract signed by the previous legislature was deemed too costly for the newly elected congress members.

16 We can also add, in a more secondary way, SDG 10 - Reduced inequalities and 17 - Partnerships to achieve the objectives

17 "Quintana Roo detectará pruebas falsas de Covid-19 con blockchain de Avalanche," Cancunissimo, July 8, 2021, https://cancunissimo.mx/quintana-roo-detectara-pruebas-falsas-de-covid-19-con-blockchain-de-avalanche/

18 "Welcome to Multi-Verse", Avalanche, retrieved July 6, 202, https://www.avax.network/

19 "Retiró congreso local sistema de blockchain por ser sobrecalificado para sus necesidades", Iriamna Caceres, QuintaFuerza, October 11, 2021, https://quintafuerza.mx/quintana-roo/cancun/retiro-congreso-local-sistema-de-blockchain-por-ser-sobrecalificado-para-sus-necesidades

The tool was simply "*overqualified for the needs of the legislative branch*[20]", as the congressional IT system already allows open access to all public data, albeit without cryptographic anchoring in a blockchain.

The example of Quintana Roo is symptomatic of the limitations of this "first wave" of experimentations trying to renovate the missions and services of trusted third parties by using blockchain technologies to better certify public information. First, the lack of resources and insufficient political support often lead these experiments to vegetate at the prototype stage. Even when they validate the technical feasibility, they rarely move beyond the proof-of-concept to meet the needs of their target users and supporting institutions (see box).

Moreover, many experiments are carried out within a single entity, recording a single type of public data, sometimes with little to no risk of fraud, of lack of transparency or of insufficient access, oftentimes with a restricted geographical area and population. In such a configuration, they are bound to reproduce siloed, vertical and impractical data structures they were supposed to replace.

Their added value might therefore be perceived as just marginal, especially since the fluctuation of transaction or gas costs associated with the use of a public blockchain -as well as their environmental footprint if they rely on a *Proof-of-Work** consensus mechanism- can send their costs through the roof and threaten their operations.

On the user side, the lack of interoperability and standards across services can make the use of blockchains to verify certified information particularly tedious, to the point of becoming prohibitive. To illustrate this point, in the absence of a common verifier to check the Covid digital test certificates of all Mexican citizens, it is hard to imagine that a user outside the state of Quintana Roo, let alone an Argentine border guard, would actually make the effort to access the evidence anchored on a public blockchain to ensure that the QR code presented by a citizen of that state is indeed valid. If the user experience is too demanding, the user may prefer to ignore the proof provided on a blockchain and go back to the process he is most familiar with: going back to square one and blindly trusting the third party.

20 "Mexico fights black market for covid tests with avalanche blockchain", Quintana Roo, June 8, 2021, https://qroo.gob.mx/iqit/mexico-fights-black-market-covid-tests-avalanche-blockchain

Securing open access to public data with blockchains: a public innovation dilemma

Proof of precedence is not evidence

When it comes to financial transactions, the information contained in a public blockchain is self-sufficient to generate the trust necessary for interactions between users of its cryptoasset.

For information that originates from "outside" the blockchain, a record in a decentralized ledger can establish a proof of precedence. The cryptographic properties of a blockchain allow the holder of an information to prove her knowledge of the information at a given moment, by signing a transaction containing the information (or a reference to it, such as a cryptographic hash) which is then integrated into a block validated at a certain point in time.

However, according to the "*garbage in, garbage out*" principle, the validity of this information is not intrinsically certified by the system, which can only verify the mathematical validity of the transaction.

Trusted third parties offer, on top of the public record, a specific added value, an evidential value that can be recognized by the community. For example, the evidential value of a notarized deed comes not only from the authority conferred by the notary's public officer status, but also from her mission to ensure due procedure, to ascertain the deed respects an authentic form and to make sure the parties are well identified and consent fully to the act. A simple blockchain anchoring might not provide these guarantees. However, a malicious, fraudulent, or failing trusted third party could record erroneous information in the register.

Provided that it is public, the use of a blockchain makes this information accessible, which can facilitate recourse for the victim of an error or fraudulent entry, but it does not, on its own, solve the problem of trust in institutions.

Network effect and critical mass

Another determining factor for a blockchain-based service to generate a sufficient level of trust and authority is the network effect. The more widespread the adoption of a public information service, the stronger the reputation of the information recorded and the easier its access. The difficulty for projects to move beyond the pilot stage, due to lack of resources or because a local deployment does not fully validate the added value, may well prevent some from reaching the critical mass of data and users necessary to prove their usefulness.

Asymmetry of needs and means

As a result, in developed countries and with liberal institutions, blockchain-based public services are rarely competitive against efficient traditional intermediaries or authorities whose jurisdiction endows

them with a strong network effect and which are able to generate substantial trust. On the other hand, these innovative services can be a credible alternative in countries affected by high levels of corruption and distrust, where institutions are systematically failing, where the administration's information systems are precarious, or for communities that do not easily fit into a specific jurisdiction (e.g. migrants and refugees, transnational communities...).

Ironically, those populations for whom blockchain-based public services has the greatest potential for positive impact are often communities with the fewest resources to develop, implement and maintain them.

The beneficiaries who would most benefit from using these services are also those for whom the barriers to entry (whether they are material, social, economic…) are most numerous and prohibitive.

Blockchains to build "stateless nations"

To really take advantage of the decentralized structure of blockchain technologies and to harness the power distribution promised by their consensus protocols, several projects have considered a much more transversal approach.

Tackling more than the data silo problem, some innovators came with the ambition of building an entire digital public administration based on blockchain technologies. As for certification services, the official initiatives were preceded by much more radical projects, steeped in anarchist or libertarian ideals. They often shared a common end goal: building entire alternatives to traditional States.

Many micronation projects have heralded the use of a public blockchain as the digital infrastructure supporting their revolutionary open administrations. Whether it is the adoption of Bitcoin by the unofficial principality of Pontinha as their official currency, the plan to create the Merit, the cryptoasset native to Liberland, a micronation nestled on the banks of the Danube River between Serbia and Croatia, which would also set up a blockchain-based legal arbitration system, or the many concepts of crypto-libertarian utopias (the sailing nation Entropy, the Floating Island Project in Polynesia, FreeSociety[21] , the Puertopia

21 "A floating Pacific island is in the works with its own government, cryptocurrency and 300 houses", Camille Bianchi, May, 18 2018, https://www.cnbc.com/2018/05/18/floating-island-is-planned-with-government-cryptocurrency-and-houses.html

project[22] , also known as Sol, in Puerto Rico…), none of these experiments or proposals have equaled in visibility, the adventure of Bitnation.

Running away with the core concepts of the crypto-anarchist ideology, **Bitnation**[23] was founded on July 14, 2014 by Susanne Tarkowski Tempelhof. Her goal was to implement a "*peer-to-peer governance system*[24]" in which anyone can join in and build a community of virtual citizens without territory or state.

This vision, fueled both by the personal history of its founder (daughter of a French mother and a Polish father living in Sweden, she worked for several years in war zones where nation-states have collapsed, in Afghanistan and Libya[25]) and by the values of Bitcoin, became possible with the emergence of the Ethereum blockchain and the rise of the first Decentralized Autonomous Organizations (DAO*).

Bitnation promised to anyone who wanted to join this unprecedented "*voluntary, decentralized and borderless nation*[26]" a variety of public services operated thanks to a set of *smart-contracts** deployed on the precursor of the "second generation" of blockchains. The first "DIY Governance[27]" toolkit comprised the "Digital ID", a digital identity tool, and, of course, a public notary service enabling users to register birth certificates, marriage certificates, property deeds and other important documents on the Ethereum blockchain.

Besides the pioneers of the crypto community and the *digital nomads*[28] sharing the founder's vision, Bitnation had more surprising *early adopters*[29]. Starting in the fall of 2015, the Bitnation Refugee Emergency Response was indeed offering migrants and refugees a Blockchain Emergency ID as well as a payment card supporting both cryptoassets and fiat currencies*, the Bitnation Bitcoin Visa Debit Card.

The mission of this device was to facilitate beneficiaries' access to services in the host country, accelerate their integration and family reunification. For migrants crossing or circumventing the Mediterranean sea -some of which come from failed States or have lost their basic documents- facing long and complex administrative procedures,

22 "Making a Crypto Utopia in Puerto Rico", Nellie Bowles, February 2, 2018, https://www.nytimes.com/2018/02/02/technology/cryptocurrency-puerto-rico.html
23 "Enter Pangea", Bitnation, retrieved July 6, 2022, https://bitnation.co/
24 "Bitnation.co", Internet Archive, March 3, 2019, https://web.archive.org/web/20190303234601/https://tse.bitnation.co/
25 "Blockchain at the service of Refugees," Audrey Bauer, Usbek&Rica, August 11, 2016, https://usbeketrica.com/fr/article/la-blockchain-au-service-des-refugies
26 Bitnation's documents, retrieved July 7, 2022, https://tse.bitnation.co/documents/
27 DIY stands for "Do It Yourself"
28 "Digital nomads" are people who adopt a lifestyle in which they travel frequently while working at the same time.
29 Refers to those individuals who are the fastest to adopt a new technology or innovation.

even a private but unforgeable identity card, with no legal value outside of its theoretical "blockchain jurisdiction", can represent an asset in their integration process. This initiative was awarded the 2017 Grand Prix of the Netexplo Forum, in partnership with UNESCO[30] .

But this recognition by a branch of the UN is not the first official contact between Bitnation and a public organization. In 2015, barely a year after their respective inaugurations, Bitnation's blockchain-based notary service was also made available to participants in the Estonian e-Residency program.

While the use of the Bitnation Public Notary does not confer legal value to documents in the Estonian jurisdiction, this partnership allows Bitnation to add support to the Estonian electronic signature for e-residents, further legitimizing its services. This announcement also demonstrated the collaboration potential between a DAO* and a sovereign State.

Thanks to these mediatic stunts, Bitnation, now registered in Belize, was able to raise, after an initial failure in 2014, more than $30 million[31] during two ICOs in 2017 and in 2018.

This money funded the launch of "Pangea," described in the whitepaper published for the occasion as a suite of decentralized tools (*smart contracts** on Ethereum, IPFS* storage and a peer-to-peer communication protocol derived from Secure Scuttlebutt[32]) with which any user or group of users can launch their own Decentralized Borderless Voluntary Nation (DBVN), based on its own constitution, functioning with its own governance mechanisms, using Bitnation's existing services or proposing new ones. Pangea also functions as the fundamental layer of this holacratic network[33] of interoperable DBVNs, acting as an arbitration system in case of disputes in the execution of services offered by DBVNs or contracts between citizens.

Pangea was additionally designed to integrate an algorithmic reputation system (called Lucy AI) essential to its "Jurisdiction as a Service" feature, by which users can designate -directly or integrated in *smart contracts**, in case of dispute, arbitrators who have demonstrated their ability to engage and collaborate with the community, in one or across several DBVNs.

30 "The Netexplo Forum celebrated its 10th edition", UNESCO, May 5, 2020, https://en.unesco.org/news/netexplo-forum-celebrated-its-10th-edition
31 "Bitnation", ICOHolder, retrieved May 17, 2022, https://icoholder.com/fr/bitnation-3557
32 "Scuttlebutt", Scuttlebutt, retrieved July 6, 2022, https://scuttlebutt.nz/
33 Holocracy (*holacracy*), which Susanne Tarkowski Tempelhof claims as one of her inspirations, is, according to Wikipedia, a "*method of decentralized management and organizational governance, which claims to distribute authority and decision-making through a holarchy [author note: a non-hierarchical network] of self-organizing teams rather than being vested in a management hierarchy*". https://en.wikipedia.org/wiki/Holacracy

At the beginning of 2018, Bitnation counted more than 12,000 citizens in over 200 *voluntary nations*. Yet, since 2019, the source code, mostly composed of disparate snippets of programs, still at the prototype stage, with the exception of certification and *token* issuance tools already standard in the blockchain ecosystem, is no longer updated[34].

A few wild statements by former developers and contributors suggest that the project always relied more on the vision and communication of the founder than on the actual development of decentralized services[35].

In the absence of serious impact measurement[36] and original code that could be reused, Bitnation was, in all likelihood, mainly "*vaporware*", a phantom product. Bitnation was not just a nation without state and borders but also without code, without any effective reality, like most of the micronation projects mentioned above.

Nevertheless, it demonstrated the concept of decentralized organizations, its merit for transnational communities willing to govern themselves beyond nation-states, thanks to a set of *open source* tools based on distributed ledger technologies. Its concept fit, at least apparently, real expectations, inspired many other projects[37] , and was surprisingly not incompatible with the existence of sovereign States.

A tool for administrations to build interoperable, federated public services

It is difficult to assess how the examples of Bitnation, the first decentralized autonomous organizations (DAOs*) and the likes have influenced public institutions in different countries.

Nevertheless, several states have decided to move beyond the implementation of pilot experiments focused on a single use case, often limited to public data and documents certification (see part 3), to announce e-government programs based on blockchain technologies.

Estonia is often cited as the pioneer country in this regard. The young Baltic state took advantage of the relative absence of public administration following the collapse of the Soviet Union to begin building an ambitious IT infrastructure to support

34 "Bitnation", Github, retrieved May 17, 2022, https://github.com/Bit-Nation
35 "The Perils of Radical Co-Creation," Tristan Roberts, Medium, March 24, 2018, https://aitheric.medium.com/the-perils-of-radical-co-creation-40fe2458281e
36 That is to say, data measuring not only the general adoption of a solution, but also evaluating the actual usage and the positive - or negative - impact thus generated on the lives of users. In the context of Bitnation, the figures might be substantial (more than 500 "Nations" and more than 5,000 "notarized contracts") but they are deprived of any precision on the nature of these communities, of these contracts (whether they have been executed or not) and of the actions they have led to. They end up telling us very little about the actual use of the platform by the users and its impact. That being said, this problem is relatively common with projects in this industry.
37 Notable examples include Nation3, CityDAO or CatalanDAO.

its newly refounded institutions after the independence in 1991, in line with its *Tiigrihüpe* ("Tiger Leap" in Estonian) strategy, promising to connect and educate its population to new digital technologies.

The production of a transverse data exchange network for the whole administration (X-Road) in 2001, then a digital identity system in 2002, and electronic voting for citizens in 2007, erected Estonia as a trailblazer when it comes to digital government[38].

In 2008, in response to a wave of cyber attacks targeting government sites during the Spring 2007, the Estonian Information Systems Authority (RIA) began working with Guardtime, a local company now headquartered in Switzerland, to test its Keyless Signatures Infrastructure (KSI) solution.

This collaboration gave birth to a first system officially launched in 2012 to secure the national register of estates of the Ministry of Justice. The use of KSI directly integrated with the X-Road infrastructure and was quickly extended to tackle new use cases with the Ministries of Economic Affairs and Communications, the Ministry of Finance, the Ministry of the Interior and finally the Ministry of Social Affairs.

Soon enough, it was securing judicial, health, property and company registry public data as well as information from the Estonian Official Gazette.

However, it is important to note that Guardtime initially insisted that its KSI is substantially different from a public blockchain. Its technology actually predates the launch of Bitcoin but shares a data structure that makes similar use of cryptography.

It allows, on the basis of a document hash, to generate a proof of existence: hashes are grouped together to form a Merkle tree* whose root is inserted into a chain-like database where each entry is cryptographically linked to the previous one, which makes the records immutable and non-reversible, similarly to a blockchain[39].

On the other hand, it does not share the decentralized and open character of a "Nakamoto" consensus protocol, since the "Aggregator" servers owned by Guardtime are in charge of forming the Merkle trees and ensuring consensus in the network[40].

In fact, it is thanks to this permissioned nature (and even private since the consensus is centralized within the same organization) that Guardtime can quickly

38 "KSI Blockchain in Estonia," Estonian Government, 2020, https://e-estonia.com/wp-content/uploads/2020mar-faq-ksi-blockchain-1-1.pdf
39 "Blockchain Designed for Supply Chains: Guardtime Supply Chain Framework," David Shorthouse, Michael Xie, Guardtime, April 2020, https://m.guardtime.com/files/Blockchain%20Designed%20for%20Supply%20Chains%20%282%29.pdf
40 "Guardtime KSI Definitions and Abbreviations," Guardtime, April 2021, https://m.guardtime.com/files/GT-KSI-DEF-v1.2-1.pdf

process the amount of data generated by compatible Estonian public services, without experiencing the scalability issues permissionless blockchains usually face.

Keeping this major difference in mind, it comes as no surprise that Guardtime did not want to associate its image with the sulphurous reputation of Bitcoin and early cryptoassets[41].

The question of the technical nature of KSI, and more specifically whether it can be qualified as a blockchain, has always been debated, including within the Estonian public authorities[42].

Estonia's e-government strategy has strongly influenced other countries looking to radically modernize the information systems that underpin public sector activities. This is particularly true of the emirate of Dubai, whose Dubai Blockchain Strategy presented in October 2016 claimed it would make Dubai "*the happiest city in the world*[43]".

Centered around three pillars -Government efficiency, Industry creation and the international *leadership*- this strategy was intended to save at least 5.5 billion dirhams per year (more than €1.3 billion), equivalent to the cost of building a new Burj Khalifa, the world's tallest building and one of the city's icons.

The "*blockchain-first"* roadmap presented by Mohammed bin Rashid Al Maktoum, Emir of Dubai, was straightforward: by 2020, all relevant government services should have migrated from paper-based processes to DLTs.

The emirate quickly announced a collaboration with Consensys, IBM and Du, the UAE-owned telecom operator, to create their own version of a "*Blockchain Platform as a Service*" (now part of Dubai Pulse, a joint initiative between Du and Smart Dubai).

Government agencies and public institutions were invited to build and launch new services or port existing ones on this system of interoperable permissioned blockchains relying on either Ethereum or Hyperledger Fabric.

No less than twenty-four use cases have been claimed to be explored across Dubai's various public institutions, internally or in the form of public-private partnerships.

41 Guardtime even stood out for its skepticism towards public blockchains and enterprise DLTs: "Guardtime", web.archive, retrieved July 21, 2022, https://web.archive.org/web/20190831005934/https:/guardtime.com/technology

42 "There is no blockchain technology in X-Road," Petteri Kivimäki, Nordic Institute for Interoperability Solutions, April 26, 2018, retrieved July 21, 2022, https://www.niis.org/blog/2018/4/26/there-is-no-blockchain-technology-in-the-x-roade.com/document/d/1I4BS2zBSODEFrsoKiTUymxjQsfl5tJFB/edit#

43 "Dubai Blockchain Strategy", Digital Dubai, retrieved July 21, 2022, https://www.digitaldubai.ae/initiatives/blockchain

They follow a set of guidelines, rules, and best practices outlined in the *Dubai Blockchain Policy* published in 2019 and fall into eight main sectors: finance, education, real estate, tourism, commerce, health, public transport and security[44].

These include basic applications such as the issuance of certificates by public universities, the registration of specialist practitioners' licences by the Health Authority, a land registry and mortgage system, a business registry, and a "Cheque Chain" that tracks cheques issued by Emirates NBD using unique QR codes[45].

A few other projects stand out by exploring more innovative applications. The "Dubai Vehicle Chain" is presented as a "*vehicle health record*" service[46] supported by the Roads and Transport Authority, with the mission of creating a registry where every stakeholder in the automotive sector could contribute to a reliable, immutable, shared record of information, keeping track of all the important events in the life cycle of each vehicle in the country (purchase, successive owners, disposal, maintenance, accidents...).

The Dubai Immigration Department is reportedly testing a record of all visitors entering and leaving the country[47]. The Dubai Pay system, which is already deployed by about 50 public and private entities and allows residents and visitors to pay for their access to some of the *smart services*, has also migrated its collection and refund system to a blockchain. Official documents claim that some cases requiring on average forty-five days of processing could now be dealt with in just two weeks, with real-time tracking[48].

The entire administration, at the local level, under the guidance of the Dubai Future Foundation and the Digital Dubai Office, drives this rapid modernization effort, combined with other initiatives to modernize public action (Dubai10X, Smart Dubai 2021, Dubai Paperless Strategy...). It is also articulated, at the federal level, with the "Emirates Blockchain Strategy" unveiled in 2018 by the same Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the United Arab Emirates.

44 "Smart Dubai turns 5!", Digital Dubai, Comprehensive Booklet, January 2021, https://www.digitaldubai.ae/docs/default-source/publications/sd_anniversary_booklet_5years_en.pdf?sfvrsn=818d909b_6
45 "Emirates NBD leads banking sector in cheque security by successfully rolling out 'Cheque Chain' at scale," Emirates NBD, April 15, 2018, https://www.emiratesnbd.com/en/media-centre/media-centre-info/?mcid_en=598
46 Blockchain in the UAE government, United Arab Emirates, retrieved July 6, 2022, https://u.ae/en/about-the-uae/digital-uae/blockchain-in-the-uae-government
47 "Govchain", UAE, retrieved July 8, 2022, https://govchain.world/uae/
48 "Emirates Blockchain Strategy 2021, GovChain, retrieved May 17, 2022, https://govchain.world/uae/; Inclusive Deployment of Blockchain: Case Studies and Learnings from the United Arab Emirates, United Arab Emirates Center for the Fourth Industrial Revolution, World Economic Forum, January 2020, https://www3.weforum.org/docs/WEF_Inclusive_Deployment_of_Blockchain_Case_Studies_and_Learnings_from_the_

This strategy is similar to the one implemented in Dubai, as it plans to build on the same momentum and reuse the same technologies. This national roadmap relies on four pillars: citizen and resident happiness, government efficiency, advanced legislation, and global entrepreneurship.

Its targets are just slightly less ambitious than the ones for Dubai: 50% of all transactions and information exchanges within the government would have to be recorded on a blockchain by 2021, saving an estimated 11 billion dirhams (nearly 2.65 billion euros), sparing 77 million hours of work and the printing of 400 million documents.

In addition to the solutions developed under Smart Dubai and deployed nationally (such as Abu Dhabi Pay, launched in May 2020[49]), the Emirates Blockchain Strategy has spawned some projects of its own. The national digital identity application, named the UAE Pass, was launched in 2018. While it does not rely directly on the use of a blockchain, its users can access a blockchain-based "*digital vault*" since 2021 to store, sign, share and verify documents with institutions across the country.

According to the Ministry of Justice, signing documents via the UAE Pass app would even have notarial value[50].

Another interesting implementation was launched in January 2019 by the Ministry of Health and Prevention (MOHAP). Hayat is a national organ donor registry developed with Dhonor Healthtech to replace the previous system of coordination between local authorities in each emirate.

With the aim of optimizing the allocation of transplants and limiting organ trafficking, Hayat is said to have already registered several thousand donors using *smart contracts** with legal force in the Emirates, facilitating the user journey for relatives, co-signing witnesses, and patients. The Hayat registry is said to rely on both official digital identity solutions and artificial intelligence to prioritize transplant allocations.

In addition to these efficiency gains, MOHAP expects to save approximately $20 million per year just by diminishing the number of regular dialysis patients[51].

United_Emirates.pdf

49 "Abu Dhabi Digital Authority launches Blockchain based Abu Dhabi Pay," Unlock Media, May 5, 2020, https://www.unlock-bc.com/news/2020-05-05/abu-dhabi-digital-authority-launches-blockchain-based-abu-dhabi-pay/

50 "UAE Government adopts 'blockchain' technology in authentication services," Emirates News Service, April 19, 2021, https://wam.ae/en/details/1395302928148

51 "Inclusive Deployment of Blockchain: Case Studies and Learnings from the United Arab Emirates," United Arab Emirates Center for the Fourth Industrial Revolution, World Economic Forum, January, 2020, https://www3.weforum.org/docs/WEF_Inclusive_Deployment_of_Blockchain_Case_Studies_and_Learnings_from_the_United_Emirates.pdf

The creation by Abu Dhabi's Digital Authority (ADDA) of a national blockchain platform to standardize and simplify data exchanges within government entities and with external partners further underlines the interoperability rationale and synergies at the heart of the strategy.

This solution, which has been piloted within the ADDA *sandbox*[52] since 2019, introduces an additional "protocol-agnostic" level of abstraction[53] allowing data to flow across the different blockchain systems used in the public sector.

It is relatively difficult to estimate with precision the concrete short-term effects of these two strategies. While the course of time has caught up with the initial horizons set out in each of them, there seems to be a significant gap between the very ambitious goals set out in the inaugural speeches and the services that are actually available to UAE citizens, residents and visitors. While a few of the public services presented here are already in production, many initiatives remain at the experimental stage.

The UAE authorities' "top-down" approach has certainly allowed them to set a common roadmap for the entire public sector, allocating significant resources, and planning for interoperability between services which would recycle solutions developed throughout the Dubai emirate and national public sectors.

Yet, it may also have caused a desynchronization between the government's strategy and the technological and organizational realities of the institutions tasked with innovating and adopting change at full speed[54].

However, what is at stake in the Emirati strategies probably go beyond the industrial deployment of blockchain-based public services. On the one hand, these major plans will necessarily have a long-term effect, at least through the acculturation and education efforts undertaken by the government[55].

On the other hand, the adoption of these strategies says certainly a lot about the country's desire for public transformation, but it also speaks volumes about the UAE ambition to communicate globally and establish its reputation as the innovative backbone of the Middle East, appealing to tourists, digital companies and leaders from around the world alike -without mentioning its immediate neighbors and competitors.

52 Sandbox: in innovation, a "sandbox" consists of an isolated test environment to experiment with a program.
53 A "protocol agnostic" solution designates a software layer that is independent of any particular blockchain protocol, enabling greater interoperability between blockchains.
54 "Emirates Blockchain Strategy 2021," GovChain, retrieved May 17 2022, https://govchain.world/uae/
55 The National Programme for AI and Blockchain Capacity Building aims, for example, to fund training for government officials as well as academic programs and scholarships.

This need to promote highly innovative national programs might have come at a cost, with some initial claims disconnected to the local context and with a lack of tracking of projects' concrete progress. But the creation of a Global Blockchain Council[56] and the massive investments towards the organization of several major international conferences are just additional signals that the blockchain strategies were not just meant to foster e-government in the country, but also to attract the innovation ecosystem, capture media attention and generate new business opportunities. In this respect, these initiatives are already quite successful.

The United Arab Emirates is not the only State supporting large-scale projects to experiment with and deploy public digital infrastructures based on blockchain technologies to modernize its public administration and to build new public services for its businesses and citizens.

The twenty-seven European Union Member-States (including the United Kingdom, as of the date of signature), joined by Norway and Liechtenstein, signed the European Blockchain Partnership (EBP) on April 10, 2018, committing to build, together, the European Blockchain Services Infrastructure. The EBSI is the project in focus for this chapter (see below).

DAOs as laboratories for new models of decentralized governance

On July 20, 2021, Rune Christensen, the founder of MakerDAO and its stable multi-collateralized crypto-asset, Dai, whose capitalization exceeded 9 billion euros in February 2022, announced in a short blog post the dissolution of the Maker Foundation.

No bankruptcy, no scandal, no dramatic *fork**, no lawsuit, not this time. By putting the entire governance of the protocol in the hands of the Maker community now organized as a fully functional DAO, Christensen announced that the project had come "full circle", that it was time to close the loop, four years after the launch of the first version of its stablecoin[57].

With the end of the foundation, the MKR holders -the protocol's native governance *tokens*- are now independently in charge of one of the flagship projects of the Decentralized Finance ecosystem (DeFi* - see chapter "Peer-to-peer electronic cash system and programmable money").

Using the governance processes built throughout MakerDAO's existence, they vote and decide together the fate of the project, introduce, discuss and adopt *Maker Improvement Proposals*, choose which cryptoassets are accepted as collateral, adjust collateralization ratios and yields, allocate funding to *core units*,

56 "Global Blockchain Council", DMCC, retrieved July 6, 2022, https://www.dmcc.ae/about-us/global-blockchain-council
57 "MakerDAO Has Come Full Circle", MakerDAO, July 20, 2021, https://blog.makerdao.com/makerdao-has-come-full-circle/

validate project teams, their budgets, missions and performance indicators, without any intermediaries nor central authorities.

MakerDAO stands out as an inspiring precedent for the whole blockchain ecosystem. It proves that the shortcomings -if not failure- of some earlier experiments such as Bitnation or the limited implementations of DLTs by traditional public and private institutions were not enough to sound the death knell for decentralized governance projects built by and for blockchain communities.

Quite the opposite, the successful progressive decentralization of MakerDAO is one of the first landmark moments for a fundamental movement in the history of blockchain technologies. *Smart contracts** are becoming mainstream with the growing adoption of Ethereum and other second and third generation blockchain protocols, bringing decentralized governance back in the spotlight, opening up the field of possibilities.

The great wave of ICO-funded projects and the emergence of decentralized finance -coming along massive increases in cryptoasset values, feverish speculative bubbles and an influx of newcomers to the space- triggered a cambrian explosion of DAOs.

Far from being discouraged by the precursory but deeply traumatic experience of TheDAO and its hacking[58], new projects are choosing every day to organize themselves as decentralized autonomous organizations to govern the functioning of one or more of their services and to coordinate decision-making within their community. Rather than relying directly and exclusively on a conventional legal structure (company, public institution, NGO...), DAOs empower open, transnational, anonymous or pseudonymous communities to gather around a set of rules and governance mechanisms inscribed in the form of one or a set of *smart contracts** recorded in and operating on a blockchain.

These communities can then make strategic decisions impacting the life of the project and manage budgets while liberating themselves as much as possible from any form of central authorities although many projects choose to keep, at least for a time, for example, a foundation duly registered in a jurisdiction for legal, financial and operational reasons, as was the case of MakerDAO during the first years of the project.

From allocating funding to open source developers to adopting a roadmap for a new project, from identifying the next asset to add to a *Decentralized Exchange** (DEX*) to shifting the yield curve of a stablecoin reserve fund, from adding an artist

58 In May 2016, after gathering more than the equivalent of $150M in this decentralized and community-based investment fund, a hacker found an exploit in the code and drained much of its assets, even forcing the Ethereum Foundation into a highly contentious hard fork ("The DAO (organization)," Wikipedia, retrieved July 21, 2022, https://en.wikipedia.org/wiki/The_DAO_(organization))

to a digital art gallery to putting a new blank plot of land for sale in a metaverse, DAOs are now one of the pillars of what some are already calling "Web 3.0", a decentralized Internet, based on blockchain technologies, where pseudonymous users would regain ownership, freedom and sovereignty over the platforms that dominate Web 2.0.

They sometimes bring together just a dozen of users, sometimes thousands, for simple objectives, such as pooling the resources of a community to participate in auctions[59], or extremely ambitious ones, such as the management of a city or even, in the footsteps of Bitnation, the constitution of a *cloud nation*[60].

As of June 2022, DeepDAO counted 4,983 DAOs in operation, with the equivalent of $7.6 billion in assets under management (the majority of these funds were concentrated in the hands of the 183 DAOs totalling assets worth more than $1 million)[61]. Eight months earlier, at the peak of the cryptoasset bubble, this amount reached $13 billion. While DeFi encompasses the bulk of these resources, new DAOs are extending the principles of decentralized governance to a wide variety of industries and use cases[62].

DAOs' implementations vary, but they are all decentralized organizations without borders nor jurisdiction, which does not mean that they are strictly "informal" either.

They are based on a set of mandatory and binding rules and mechanisms compiled in the form of computer code registered in a second or third generation blockchain as *smart contracts** (see Introduction).

Decisions are most often taken *via* community votes, the results of which are automatically and transparently executed thanks to *smart contracts**. The community also revolves around discussion forums and coordination processes happening "*off-chain*", outside the blockchain.

Staying true to the BIP model, proposals are often first introduced and discussed in forums or on social networks that are more or less open (Twitter, Discord, Telegram...) before being put to the vote to ensure their relevance and the consensus within the community.

This open and collaborative structure is often claimed to be democratic and horizontal. While it is clear that DAOs today represent fascinating laboratories of alternative governance models, variations in voting patterns establish fundamental

59 Several DAOs have emerged as a vehicle for a new form of crowdfunding: notable examples are the unsuccessful attempts to buy one of the original copies of the U.S. Constitution, the purchase of the Dune movie adaptation script imagined by Jodorowsky, or the campaign that raised $ 6.7 million for the Ukrainian NGO Come Back Alive.
60 "Building a DAO governed Crypto City," City DAO, retrieved July 21, 2022, https://www.citydao.io/; "A New Nation State on the Cloud," Nation3, retrieved July 21, 2022, https://nation3.org/
61 "Organizations," DeepDAO, retrieved May 17, 2022, https://deepdao.io/organizations
62 "15 ways the world is transformed by DAOs", Aragon, July 6, 2021, https://blog.aragon.org/15-ways-the-world-is-being-transformed-by-daos/

distinctions and invite us to draw a much more nuanced landscape.

Since DAOs cannot establish centralized "voter lists" like states with access to the physical identity of voters, users prove membership in the open community by holding of a cryptoasset or by putting that crypto-asset in a fund in exchange for a dedicated governance *token*.

One's right to participate in the DAOs' votes can thus be checked automatically, without the need to reveal voters' identity. In most cases, the weight of each ballot in the results is also proportional to the amount of *tokens* held by each voter. These *stake-based* votes are meant to guarantee the openness and decentralization of the system, since any user can acquire *tokens* and join the decision-making process at any time, but also limit certain attacks (identity theft, ballot box stuffing, etc.).

It also ensures that each participant to the vote has some "skin in the game", since the value of one's stake is directly correlated to the development and growth of the project. This incentivization mechanism also increases the cost a malicious actor must bear to subvert the system as it is requires that voter to acquire a great number of *tokens* and use them in a way that could make them completely lose their value.

In practice, this type of governance often presented as "meritocratic" comes with structural biases and can quickly degenerate into plutocracy. The level of participation in DAOs is often very limited. Votes can be numerous, some DAOs setting up several elections per week, and users with small *stakes* may have very little incentive to invest the time and effort required for regular active participation in one or several DAOs.

On the other end of the spectrum, "*whales*"[63] enjoy a colossal weight in the governance of a DAO, especially if, as *early investors*, they have acquired the *tokens* at very advantageous prices before they were publicly distributed or put on the market[64]. They are also logically the players the most incentivized to weight in at every stage of the governance game (voting, making proposals, influencing discussion…).

One way many DAOs address "election fatigue" or "rational disinterest" among small stakeholders, maximize their chances to secure a quorum, and increase the legitimacy of the votes' results is to allow for delegated voting[65].

This process tends to increase community participation, but may also boost the power of *whales* who are logical recipients for delegations since they can invest the most

63 "Whales" are a common nickname given to holders of a large amount of crypto-assets.
64 In the case of Compound, the four addresses with the largest stake at the time of writting are investment funds, while the 5th and 6th top addresses belong to the co-founders of Compound Labs, the company behind Compound. Together, they represent more than 40% of the total amount of votes available.
65 A voting system in which users of a blockchain grant their voting power to other users who then vote for them with the aggregated stake.

resources in the governance of DAOs and are oftentimes part of the loudest voices in forums and on “CryptoTwitter,” .

These kinds of barriers to entry can even occur further upstream in the governance process. **Compound**, one of the main decentralized money market solutions whose influential governance model has been the blueprint of many DAOs (Uniswap, Radicle...), requires that any governance proposal that would modify the *smart contract* needs to be submitted by an address that owns or has been delegated at least 25,000 COMPs (the value of a COMP swings between $150 and $30 in the 2nd quarter of 2022, after peaking at $800 in May 2021)[66].

This measure was initially enforced to limit the risk of spam and ensure that proposals would have some minimal support before being submitted to the vote, yet it potentially forced small actors to convince the community and receive delegations before they could even officially submit the proposal, or to rely on one of the *whales* to introduce the proposal on their behalf. After heated community discussions, the Compound community has implemented two additional ways to participate in governance.

Users can now initiate a proposal putting down only 100 COMPs via a *smart contract** which then collects the delegations necessary to validate the 25k floor mentioned above, and the community now maintains a whitelist featuring a limited number of regular and reputed contributors who may propose evolutions without having to validate the delegation thresholds.

Decentralized governance can suffer from other problematic biases. Since the ballots are not private but publicly available on the blockchain, even before the vote comes to a close, the opinion of one or several whales can influence the final results and convey a skewed impression of wide consensus.

For example, small holders who might oppose a measure heavily supported by whales may be completely discouraged and decide not to even submit their ballot, especially if such a vote cost them more than time (on-chain voting may involve network fees or gas) or if they fear any form of retaliation enabled by the lack of privacy. Stake delegation may even reinforce this bias, as the delegate’s vote may not reflect the opinion -or lack thereof- of the individual stakeholders she represents.

The consensus resulting from DAO votes that lack “fairness”[67] might be greatly overestimated, with potentially seriously underrepresented minority opinions.

66 This floor was originally 100k COMP, before being lowered to 65k in July 2021 and then 25k in March 2022, as the number of addresses able to sponsor a proposal went from less than a dozen, to a dozen and then to about thirty addresses.
67 Fairness describes, in voting theory, the absence of preliminary results or estimates prior to the term of a vote.

Another critical issue that comes with the lack of voters' privacy is the possibility to easily buy off votes and establish automated and organized corruption schemes. Since the participation of a public address in a vote and its choice can be openly verified, anyone can propose to reward voters submitting the right ballot and influence the governance of a DAO at scale[68].

Even crazier, with the explosion of the value of DeFi and the growing financial stakes involved in decentralized governance protocols, several platforms such as Convex[69] or the aptly named Bribe Protocol[70] emerged. Their value proposition is simple: offering decentralized and automated vote buying systems to connect stakeholders willing to safely monetize their governance token and others who want to increase their influence[71]. Some stake-based voting systems are also exposed to "governance attacks".

If governance tokens are widely accessible and very liquid, malicious users can very well temporarily buy and resell or just borrow a large quantity of tokens, gathering a significant stake just for enough time to propose and/or vote a measure favorable to their personal interest, regardless of the short or long term fate of the concerned DAO[72].

Several alternatives have been proposed, however, to make participation in DAOs structurally more democratic. Some DAOs have adopted quadratic voting, a system in which each voter gets a vote "credit" they can distribute among potential outcomes.

A voter can allocate all of her votes to one choice, but the cost of each additional vote increases quadratically (or conversely, the weight of each new vote decreases quadratically).

This type of voting, while maintaining various voting power for voters depending on their stake, therefore favors choices that are supported by the largest number of participants and reduces the possible influence of the wealthiest voters[73]. **Gitcoin** offers a participatory investment platform where contributions are matched by a fund according to a quadratic rule[74].

68 In a July 2018 paper, On-Chain Vote Buying and the Rise of Dark DAOs, Daian, Kell, Miers, and Juels already listed several structural reasons why voting systems on public blockchains can enable efficient and automated vote buying markets, either directly in a blockchain with dedicated *smart contracts*, or off-chain.
69 "How it works," Convex, July 6, 2022, https://www.convexfinance.com/
70 Bribe documentation, accessible at https://bribe.gitbook.io/bribe/
71 "Pay-to-Play Governance Builds Steam as Bribe Raises $4M," Andrew Thurman, Coindesk, January 22, 2022, https://www.coindesk.com/tech/2022/01/12/pay-to-play-governance-builds-steam-as-bribe-raises-4m/
72 Justin Sun, the sulphurous founder of the Tron blockchain, has made himself a reputation of attempting to subvert decentralized governance processes by temporarily acquiring a significant stake in a DAO then trying to force decisions favoring Tron and its ecosystem. Notable examples of such DeGov hacks include the hostile takeover of Steem, and more recently attempts to favor Tron's cryptoasset in MakerDAO and Compound. This can be mitigated by forcing voters to lock their tokens for a certain time before they are taken into account.
73 It should be noted that this voting method can be subject to "Sybil attacks".
74 In such a system, if one project receives a $100 contribution and another receives ten $10 contributions, then the first project will receive a $10 match from the Gitcoin fund, the second a $190 match.

It has enabled the allocation of cryptoassets worth more than $50 million to open source "public good" oriented projects in the blockchain ecosystem[75].

Other initiatives are designed to better align voting in DAOs with democratic principles by substituting the ownership-based voter identification system with new authentication tools. These alternatives to "*coin voting*" try to better distribute governance power while still preventing "Sybil attacks"[76]. Besides *self-sovereign identity* (SSI) projects that could restore a "one user one vote" rule by proving that a public key is linked to a single member of the community (see chapter "Identity and ownership"), POAP, for Proof of Attendance Protocol, allows for instance to attribute an NFT to retribute users for their real activity in their community, such as regular contributors to a project's source code, wiki or forum, events organizer or participants…

This type of NFT*, which remains difficult to attribute without an identification system linking the *off-chain* and *on-chain* identity in a fully decentralized setting -a core developer needs to link her Github account and her public address, can then be attributed a custom voting power in the DAO without requiring any financial investment, in addition or in substitution to the "*stake*".

In a similar vein, **Snapshot** (see *below*) and **Orange Protocol** have announced a partnership whose goal is to let DAOs weigh votes according to the reputation of each voter.

The **democracy.earth** foundation wants to go even further with its "Proof of Humanity" project, a decentralized identity system where any human being can obtain a unique digital identity that he or she can then use in communities on a blockchain (see chapter "Identity and Ownership").

To join the "Sybil-resistant" list of real human beings, carried by the project, participants must provide at least a name by which they are known (this can be a public username), as well as a picture of their face. To finalize the submission, they need to upload a video showing them with no glasses, masks or accessory, in which they hold a written message presenting the Ethereum address that will carry the "proof of humanity" and declare legibly: "*I certify that I am a real human and that I am not already registered in this directory*".

A deposit is required to initiate the peer-to-peer verification of each application. Any member already authenticated may validate the request or create a claim if she considers it invalid or fake (duplicate, non-existent or deceased person...). If the application receives a greenlight, the deposit is refunded, and the user benefits from a public key certified as belonging to a unique human being, as well as the right to receive UBI (Universal Basic Income)

75 "Gitcoin is the community of builders, creators, and protocols at the center of open web ecosystems," Gitcoin, retrieved May 17, 2022, https://gitcoin.co/about
76 The creation of multiple digital identities linked to or controlled by a single entity.

tokens, a "universal income" system supported by democracy.earth.

In case of a claim contesting the decision, the dispute is settled thanks to an arbitration court that is also decentralized, using the Kleros protocol. If the claim is rejected and the application finally rejected, the verifier pockets the deposit as a reward for her vigilance.

Interestingly enough, DeFi and Web 3.0 most vocal advocates consider financial inequalities or barriers, translating in asymmetric voting power or unequal access to some mechanisms (e.g. proposal submission), as natural if not beneficial for decentralized governance, since they would allow for a better alignment between participants and their economic interest in the success of a project.

Yet, they see technical accessibility with a different eye, as substantial efforts have been invested in drastically lowering the technical barriers that could scare off investors and project leaders.

Many services such as **Tally** or **Boardroom** offer investors user-friendly interfaces to track current and past proposals and ongoing votes in major DAOs. As transaction fees and thus the cost of *on-chain* voting could fluctuate to painful heights, alternative "signalling" solutions are emerging, such as **Snapshot**, which is used by more than 6,000 organizations to list proposals and let users signal their support or opposition *off-chain*, maintaining some level of decentralization, using the InterPlanetary File System (IPFS*) protocol (see also "Web 3.0, Arts & Science" chapter).

Snapshot consults, at a given time, the blockchain to establish "electoral rolls" and ballot weight depending on the distribution of governance *tokens* in a community. DAOs can thus test the opinion of their communities before launching a binding and potentially costly vote on their blockchain infrastructure.

The multiplication of "no-code" tools that let anyone create new DAOs is even more symbolic of how decentralized governance is becoming more universally accessible.

These platforms, often themselves organized as DAOs, build open source tool boxes requiring as little technical knowledge as possible and now contribute to the emergence of standards in the blockchain ecosystem.

With these tools, anyone can customize *smart contracts** based on typical blueprints, tweaking the governance model to match the specific goal of a project and the community that supports it, before deploying it on a blockchain. Here is a quick non-exhaustive overview of these DAO making platforms and their specificities.

DAOhaus lets its users create their own DAO based on the 2019 Moloch standard on Ethereum, Gnosis, Polygon, Arbitrum or even Celo.[77]

DAOhaus presents its users with five models, which can be easily customized through half-dozen parameters. It had already served as a launching ramp for roughly 2,000 DAOs by the end of 2021, for more than 10,000 unique participants in these organizations[78].

DAO designers can even conceive new features thanks to a large number of "Boosts" plugins or by calling upon functionalities of external *smart contracts** via its "Minions" feature[79].

DAOstack is a different *open source* platform for generating DAOs. Its Alchemy tool facilitates the creation of DAOs in a few clicks and sets itself apart thanks to its "holographic consensus" tools[80] making use of the platform's native GEN *token*. Users of decentralized organizations created through DAOstack can bet their GENs on the proposals which seem the most likely to be adopted. This "prediction market" applied to governance is directly inspired by the concept of "futarchy"[81] and acts as a catalyst for the aggregation of divergent interests within the community, quickly bringing greater visibility to the most consensual proposals, or at least those most likely to be supported by a clear majority. In spite of this interesting feature, DAOstack never really achieved significant adoption in the ecosystem.

With such a hype around DAOs, some platforms chose to focus their efforts on a single use case. Juicebox, for instance, was specifically meant to help users create DAOs for crowdfunding.

Users can customize a set of parameters and adjust the economic variables related to the project and its *tokenomics* in an appealing graphical interface[82]. Juicebox also acts as a directory for the more than 600 crowdfunding projects that were created on the platform and which in turn funds its own JuiceboxDAO, *via* a small fee (2.5%) on each withdrawal from the treasury of one of the hosted DAOs.

77 Moloch was designed to manage funds in a decentralized manner. It features a "ragequit" mechanism to protect minority investors in the DAO. The ragequit gives users the possibility to "slam the door" of a DAO in case of irreconcilable disagreement with a decision adopted but not yet implemented, taking with them a share of the funds proportional to their weight in the governance.
78 "2021 Year in Review," DAOHaus, retrieved May 17, 2022, https://daohaus.club/review/
79 "*Minions allow your DAO to call arbitrary contracts, which allows you to do many things like manage Ethereum Name Service, collect NFTs, manage cash in DeFi, etc.*" "Minion FAQ," Minion, retrieved Jul 21 2022, https://daohaus.club/docs/users/minion-faq/
80 "Holographic Consensus - part 1," Matan Field, Medium, November 12, 2018, https://medium.com/daostack/holographic-consensus-part-1-116a73ba1e1c
81 "Futarchy: Vote Values, But Bet Beliefs," Robin Hanson, mason.gmu.edu, retrieved May 17, 2022, http://mason.gmu.edu/~rhanson/futarchy.html
82 *Tokenomics* is a contraction of *Token* and *Economics*. It defines the design of a token, its features, its economic fundamentals and governance variables.

Out of all these "meta-DAOs" platforms, **Aragon** is probably, along perhaps DAOhaus, the most influential. During the year 2021, more than 1000 DAOs were created with Aragon (mainly on Polygon, Ethereum or Harmony).

Founded in 2016 by Luis Cuende and Jorge Izquierdo, setting out to ensure the freedom and sovereignty of individuals and online communities by developing new free and open tools for coordination and decentralized governance, Aragon stands out with its vertically integrated "suite" of tools to cover all the governance needs of an organization operating in a decentralized manner.

The Aragon Client allows anyone to easily set up and deploy a DAO. Aragon Connect acts as an interface between the DAO and other applications. In case of a dispute or a gridlock, Aragon Court takes over and offers a decentralized arbitration system to resolve disputes that may arise within the DAOs.

This tool supports a network of "*guardians*" who follow an established process of nomination, reception and evaluation of disputes.

Each selected dispute leads to the attribution of a dedicated jury that will debate then deliberate through a vote to issue an arbitration that can be appealed by one of the the parties. More recently, Aragon has announced Voice, its own *off-chain* voting tool competing with Snapshot, as well as Govern, a new DAO creation and management system designed to build on the standards used by Aragon Client, adding an "optimistic" governance system, much more efficient in terms of associated costs (*gas*) on the blockchain[83].

Finally, in July 2021, Aragon also bought **Vocdoni**, a Catalan startup developing decentralized governance and e-voting tools catering to traditional organizations and political entities.

The acquisition of Vocdoni by Aragon highlights the current effervescence around DAOs and the actual permeability between the efforts to develop decentralized governance tools for the "Web3.0" ecosystem and those aimed towards regular public institutions and civil society organizations.

83 With Govern, DAOs can mandate stakeholders to act as executors, giving them permission to initiate binding actions (e.g. after a prior *off-chain* vote on Voice) without going through an *on-chain* vote. These decisions are implemented after a delay during which community members can challenge the action through the Aragon Court. This division of powers between deliberative, executive and legal branches responds both to economic and technical constraints (increase of gas costs) as well as organizational constraints (repetition of votes, even for mundane, consensual measures) by reintroducing a familiar governance structure in the DAO ecosystem.

Focus *European Blockchain Service Infrastructure* (EBSI)

Few projects can better capture the rich dynamics connecting blockchain technologies and democracy as well as the European Blockchain Service Infrastructure (EBSI).

This flagship commitment is part of the European Blockchain Partnership (EBP) signed on April 10, 2018 by all the then-EU member states (including the United Kingdom), joined by Norway and Liechtenstein and builds upon the Connecting Europe Facility (CEF) funding plan to create an international blockchain-based infrastructure that will host a new generation of pan-European digital public services.

Gathered in the EBSI, the Member States could build a shared dynamic, identify common use cases and propose mutual solutions servicing all the European citizens. The applications elaborated as part of the EBSI would not be just basic "ports" of existing public services on a blockchain setting.

Instead, the EBSI is meant to support the emergence of innovative cross-border services relying on a network of public and private trusted third parties that would directly benefit from the transparency, decentralization, security, and interoperability brought by a decentralized ledger to deliver greater value to EU citizens.

Five key principles are baked in this project: the pursuit of the public good, the operation under a shared governance, the use of harmonized standards, the commitment to open source development and of course the compliance with European law, particularly with regard to data protection.

The choice of *open source* development and the elaboration of interoperable standards at a European scale are essential factors for the success of EBSI and represent a drastic turn from earlier strategies where each Member State would attempt to build an infrastructure on their own with no coordination with its neighbors. Not only does this collaborative approach unlock the mutualization of R&D and infrastructure costs, it significantly augments the potential impact of projects as experiments delivering value locally could scale more easily across the partnering States.

The EBSI does not only grease the wheels at the national level, it also furthers public-private cooperation since the European innovation ecosystem is directly involved in the design process and the creation of standards. Innovative startups eager to build new offers catering to the European public at large would now have this market-friendty infrastructure and unified standards to build upon.

The EBSI has been granted a total investment of 38 million euros for the years 2021-2022[84]. This initial provision funded the creation of a permissioned blockchain network made up of 36 nodes and operated by public institutions from the 23 signatories of the European *Blockchain* Partnership (EBP).

This network runs on modified versions of Hyperledger Besu and Fabric (PoA) consensus protocols -support for other blockchain networks, including public ones might be added in the future- and already counts a dozen compatible *wallets*.* On top of this interconnected infrastructure, the EBSI's technical architecture also features a "*chain* and *off-chain* storage" layer where the encrypted data involved in the use cases are stored and a "*core services*" layer which gathers standardized APIs designed to facilitate the development of service applications.

The EBSI follows some kind of a leitmotif: all of its use cases revolve around turning centralized data storing and verification systems into decentralized certification and sharing solutions, in a way that resembles *self-sovereign identity* models. In order to prove a personal information, first asking a trusted third party to generate a digital or physical document, then sharing it with a verifier which will in turn get in touch with the issuer to confirm the document is authentic, users of an EBSI service request trusted third parties to generate verifiable digital certificates (*verifiable credentials*) that they can store in their *wallet** and whose authenticity can be confirmed by a verifier directly *via* the EBSI encryption scheme.

These certificates follow a W3C global standard and should be recognized at least throughout participating countries. EBSI services have the potential to give back to users the ownership and control over their personal data, which they could share in a selective and "atomic" way, revealing only the pertinent identity attributes (e.g. the fact a betting website user is over 18 years old), without disclosing any additional information contained in the document they would have otherwise transmitted to the verifier (with the same example, all the other information contained on an ID document).

The EBSI should also spare verification costs and reduce the risk of fraud, especially when it comes to cross-border procedures.

Seven use cases have been ranked as top priorities by the members of the European Blockchain Partnership. A first ongoing wave of experiments is dedicated to digital notarization, self-sovereign identity (see chapter "Identity and Ownership"), diplomas and training certificates management, as well as the implementation of a unique European social security identifier (European Social Security Pass, ESSP). In a second phase,

84 "Annex to the Commission Implementing Decision on the financing of the Digital Europe Programme and the adoption of the multiannual work programme for 2021 - 2022", European Commission, Nov 10 2021, https://ec.europa.eu/newsroom/repository/document/2021-46/C_2021_7914_1_EN_annexe_acte_autonome_cp_part1_v3_x3qnsqH6g4B4JabSGBy9UatCRc8_81099.pdf

efforts will be extended to the processing of asylum-seeking applications, the deployment of a European bond financing platform for SMEs and Trusted Data Sharing solutions.

Based on a common infrastructure and *open source* standards federating European states, involving strategically the innovation ecosystem in the design and development of new interoperable public services, the EBSI is a remarkable example of how blockchain technologies can be used to modernize public action and to improve trust, not only between institutions and citizens, but also potentially between all the actors of the European Digital Single Market. In that sense, the EBSI's approach transcends many limitations that crippled previous blockchain-based e-government projects.

The EBSI is structured around a vision infused with the European values of transparency, trust, freedom and privacy. This initiative is also articulated with EU digital regulations and taps into resources from national and continental levels.

Beyond these coherent foundations, the EBSI also benefits from its sheer size. While blockchain technologies are still struggling to achieve mainstream adoption and impact (especially beyond financial use cases), EBSI's potential user base is a clear asset: European institutions and innovative companies are incentivized to invest in services that could directly tap into a wide population of potential users, while at the same time pooling the risks and reducing the cost of entry for actors, in the public sphere or beyond, that are lacking the resources to really invest in R&D on their own.

Above all, in parallel with the European legislative efforts to better regulate Big Tech platforms, the progressive deployment of the EBSI may be a catalyst for European sovereignty and integration. Not only does it have the potential to harness blockchain technologies to build user-centric services accessible to citizens and businesses across Europe, the EBSI could better equip public institutions lagging behind in terms of digitization with common decentralized tools that would generate sustainable trust and support democratic, transparent, and shared governance.

The EBSI gives us a glimpse at what a system at the intersection between European values, its digital ambition, and the value-added of decentralized technology could look like. If successful, it could strengthen the sovereignty and technological independence of its Member-States, but also of its citizens, delivering actual value while better protecting their data and online freedom.

It is too early to say whether the EBSI will make this vision come true, whether its services will meet the needs of European citizens and achieve adoption.

As it is the case for every innovation project, the EBSI involves uncertainty, risks of betting on the wrong standards, of misaligning investments and ambitions.

The project will have to survive the hazards of its collaborative governance, involving thirty states with different national policies and economic situations and keep up the pace of the bubbling blockchain ecosystem.

But if it succeeds in providing efficient and accessible services to all, then this model could not only transform the digital everyday life of European citizens, but its vision and standards could also spread beyond the borders of Europe[85], contribute to the emergence of interoperable public services around the world and constitute one of the pillars on which another Internet could be built. One that would be more decentralized, more open, where users can interact online with each other, with public institutions and private entities, in a trustworthy and secure manner, where they can freely choose which tools and services best fit their needs without ending up locked in a centralized platform, remaining at all time the ultimate owners of their personal data.

85 Like how GDPR transformed the global digital landscape, as described by Anu Bradford in *The Brussels effect*.

ISSUES AND QUESTIONS

There is a remarkable dialectic between blockchain, e-government and democracy. In just a few years, the emergence of distributed ledger technologies as alternatives to traditional trusted third parties paved the way to the current proliferation of DAOs* and their decentralized governance models.

The early State-sponsored experimentations trying to use blockchain technologies as a tool for their digitization set the stage for large-scale open source infrastructures where public institutions and startups collaborate.

There is a paradoxically shared dynamic between an innovation ecosystem that brings together pseudonymous or anonymous individuals under the transnational (or even "a-national") banner of a company, an open community or a DAO*, and States that are seeking to modernize their public institutions to better meet the needs and tackle the challenges of our increasingly digital societies.

This strange competition for more horizontal governance systems, for more transparent, efficient public services once placed back in the current context, might prove to be essential.

On the one hand, GAFAM[1] and other "Big Tech" platforms have accumulated immense powers and organize a substantial part of our digital activities, mediating an ever-growing part of our socio-economic relationships.

At the same time, our democracies are going through a fundamental crisis, with a profound erosion of trust in intermediaries, public institutions, and authority figures, whether they belong to the scientific, media or, of course, political spheres. According to a 2020 meta-analysis by the *Centre for the Future of Democracy*, the average rate of dissatisfaction regarding democracy, measured in 77 democratic countries, stands at an alarming 57.5%[2].

1 GAFAM is an acronym for the following tech giants: Google (Alphabet), Apple, Facebook (Meta), Amazon and Microsoft.
2 "Global Satisfaction with democracy," Foa, R.S., Klassen, A., Slade, M., Rand, A. and R. Collins, Bennett Institute for Public Policy of the University of Cambridge, January, 2020, https://www.cam.ac.uk/system/files/report2020_003.pdf

The Pew Research Center reported in 2021 that more than two-thirds of the population in the United States, Italy, Spain, Greece, France, Belgium, South Korea and Japan believe that their political system needs to be completely reformed or needs major changes[3].

There seems to be an evident need for new forms of governance, for alternatives that would be more participatory, transparent and decentralized. This was already one of the main motives behind the creation and evolution of blockchain technologies and cryptocurrencies, and the emergence of DAOs, acting as laboratories for a multitude of decentralized governance systems, might be considered as a partial yet concrete achievement of this ambition.

However, it would be unfair to judge the full potential of decentralized governance only in light of the very imperfect current DAO landscape. First, because not all of them were designed to be democratic. The influence of libertarian and anarcho-capitalist ideologies on the blockchain ecosystem, the sudden creation of an astronomical amount of value, and the reliance on *stake*-based voting systems led some DAOs to tolerate inequalities and plutocratic centralization, although it may be incompatible with the proper exercise of democracy[4].

Secondly, because many voices are progressively denouncing these issues[5] and proposing innovative solutions that might ripple outside of the blockchain world and contribute to solving problems that are also common to good old democracies: insufficient public goods funding, corruption, centralization of political power in the hands of the wealthiest…

Finally, while this might be a weak argument in defence of cryptoassets in general, decentralized governance remains in its infancy when compared to democratic societies

3 “Citizens in Advanced Economies Want Significant Changes to Their Political Systems,” Richard Wike, Janell Fetterolf, Shannon Schumacher and J.J. Moncus, pewresearch.org, October 21, 2021, https://www.pewresearch.org/global/2021/10/21/citizens-in-advanced-economies-want-significant-changes-to-their-political-systems/

4 “Blockchain Technology and Decentralized Governance: The Pitfalls of a Trustless Dream,” Primavera De Filippi, Decentralized Thriving: Governance and Community on the Web 3.0, February 19, 2020, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3524352

5 “Moving beyond coin voting governance”, Vitalik Buterin, Vitalik’s Buterin website, August 16, 2021, https://vitalik.ca/general/2021/08/16/voting3.html

that are the result of centuries of experimentations and conflicts. The recomposition promised by DAOs cannot instantly solve all the problems on which our States trip and stumble.

Rather than giving undue credit to the caricature of an "old world" suddenly disrupted and toppled by cyberpunk-inspired organizations, or the equally fruitless caricature of denying the potential and novelty of DAOs, this chapter emphasizes how porous the frontier between these two worlds can be.

Decentralized governance, which is subject to many constraints our public institutions also face, represents a spectacular opportunity to step aside, question, deconstruct and reconfigure our democratic systems in critical time.

DAOs can be great testing grounds to experiment with technological innovations that could make administrations and the public services they deliver more resilient, transparent and efficient.

They can prove the value of alternative, polycentric, and sovereign governance models and participatory decision-making tools that could be replicated inside the blockchain ecosystem but also by public institutions around the world, to the benefit of citizens. DAOs already stimulate democratic innovation, with concepts such as liquid democracy and quadratic voting seeing a new wave of interest (for instance, quadratic voting was used in 2019 by Colorado's Democratic senators to prepare their budget legislation[6]).

To conclude, just as the competition brought by decentralized governance could spur governance innovation and act as a catalyst for a democratic rejuvenation of States and public bodies, DAOs also have much to earn in such a comparison -if not a convergence.

Although the "tokenization", the "commodification" of DAO users' governance rights creates "skin in the game" conditions and incentivization mechanism, the profit maximization inherent to free market and to the game theory principles that underlie consensus protocols might

6 "Colorado Tried a New Way to Vote: Make People Pay-Quadratically," Adam Rogers, Wired, April16, 2019, https://www.wired.com/story/colorado-quadratic-voting-experiment/

induce an "over-financialization" of governance[7].

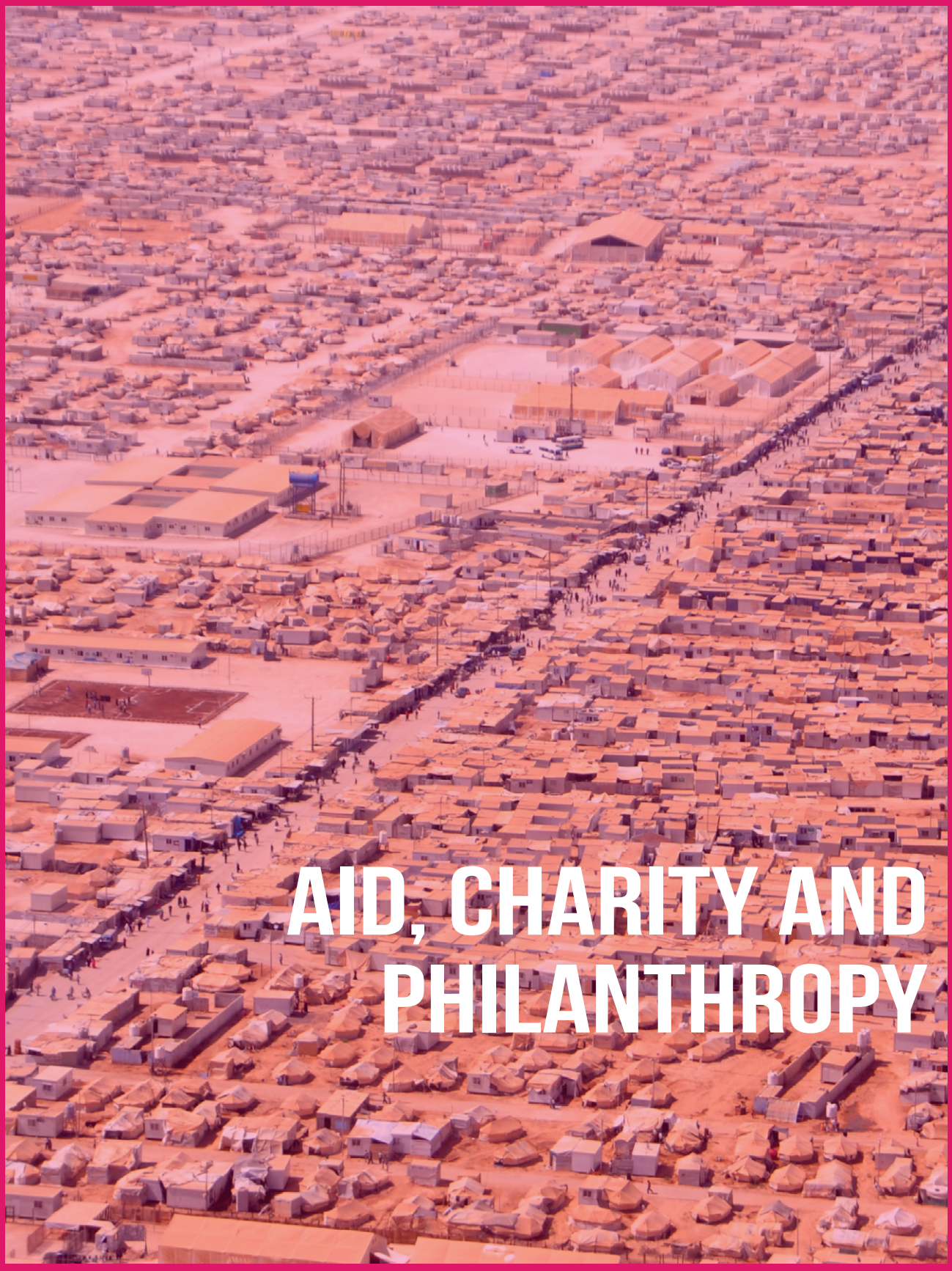
Financial and speculative logics can take precedence over the a project's long term goals or over the decentralization, horizontality, independence or transparency objectives which led a community's to organize as a DAO, even justifying very faulty systems that would seem unfair or undesirable in any functional democratic society.

Markets for buying and selling governance rights such as Bribe[8] are undeniable examples: they may increase the transparency around corruption -a phenomenon that does exist outside the blockchain- but it would be absurd to consider them as upsides and not as existential risks to the design, adoption, and operation of credible, resilient and sustainable decentralized governance systems. States have lessons to draw from DAOs, but DAOs also have much to learn from the successes and failures of existing democratic societies.

In this respect, an initiative such as the *European Blockchain Service Infrastructure* (EBSI) gives a preview of the tremendous potential well designed blockchain-based public services might have and the positive impact they might deliver.

The EBSI and other projects of its kind can drive standardization and mainstream adoption for these technologies, contributing to more trustworthy institutions and participatory decision-making mechanisms that are essential to achieve sustainable development goals. But for decentralized governance to be successful today and in the long run, safeguarding and even furthering democratic principles such as accessibility, inclusiveness, plurality in decision making, or confidentiality of private data will prove to be essential.

7 This process fits nicely within Polanyi's 1944 "marketization" concept (*The Great Transformation*), where the economy tends to commodify things that were previously not encapsulated by the market. Current proposals such as POAP and soulbound tokens would then be the equivalent of the "social protection" reforms that are the second part of his "Double Movement".
8 Bribe Protocol: https://app.bribe.xyz/



AID, CHARITY AND PHILANTHROPY

AID, CHARITY AND PHILANTHROPY

Number of projects in the directory: 107

Number of active projects: 31

Name of active projects: Aidcoin ; Alice.si ; AntLove ; Bitcoin Beach ; Bitcoin lake ; Blockchain Charity Foundation ; Brac blockchain pilotes ; Colony ; Doingud ; Engiven ; eSolidar ; Exalti ; Givecrypto ; Giveth ; GiveTrack ; Homeward ; ImpactMarket ; Little Phil ; Monerium ; NFTb ; Pinkcoin ; Popcorn network ; Promise ; REDD-Chain ; Seeds ; Social Alpha Foundation ; The Giving Block ; UnBlocked Cash by Oxfam ; Urban Array ; Venezvit ; WFP Building Blocks. *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

For international solidarity actors, the promise of blockchains is seductive: simplify their bureaucracy and ensure traceability of funds to the beneficiary, and facilitate the deployment of emergency measures during humanitarian crises. Beyond the activities of international organizations, non-governmental organizations and associations, new forms of humanitarian aid without intermediaries between donors and recipients seem to be developing. More than a hundred blockchain initiatives have emerged, of which 33 are active to date in the fields of development aid, donations, charity and humanitarian crises. The humanitarian aid sector, development aid, fundraising and collecting donations for bitcoin initiatives are intimately linked to the themes of "digital identity" and "peer-to-peer electronic cash system and programmable money" which we deal with in two separate chapters.

Since as early as 2013, non-profit associations such as **BitGive** or startups such as **AidCoin**[1] or **Pinkcoin**[2] have been approaching International Organizations and Non-Governmental Organizations whose missions are by nature aligned with the Sustainable Development Goals. For example, the American nonprofit **The Water Project**[3] has been providing clean

1 "Start accepting donations with 23 cryptocurrency on your website", Aidcoin, retrieved June 27, 2022, https://www.aidcoin.com/
2 "Blockchain Based Donation Platform For Social Impact", PinkCoin, retrieved May 10, 2022, https://pinkcoin.com/
3 "You can help solve the water crisis", The Water Project, The Water Project website, retrieved May 10, 2022, https://thewaterproject.org/

water and sanitation in sub-Saharan Africa since 2007. In 2014, The Water Project had an account on the Coinbase exchange platform and was accepting donations in bitcoins,[4] some of which will eventually be converted to fiat currency only in 2025.[5]

In 2015, UNICEF conducted an initial experiment on the public Bitcoin blockchain to test an "immutable identity system", explaining that *"if we could take a person's photo, link it to their personal information (date of birth, name, etc.), encode those elements, and publish a cryptographically secure link to the encoded information on the blockchain, that link, because it would be on a public network and without permissions, would last 'forever' and constitute an immutable identity"*.

In 2016, UNICEF set up a venture capital fund to invest in technology startups in emerging markets.[6] Two years later, the fund has 72 investments in data science and artificial intelligence, blockchain and extended reality, including 33 in startups based in countries where UNICEF is active.[7]

A dozen other UN agencies have initiated a number of blockchain projects as of 2017, conducted individually or collectively, in areas as varied as supply chains, digital currency payment and money transfer, livestock tracking, digital identity, and land registration.

A report by the United Nations Joint Inspection Unit calls these initiatives *"unprecedented opportunities for inter-agency collaboration"*[8] in 2020, while taking measure of the scope of the work to be done to implement a cross-agency roadmap.

For Thomas Davin, Director of the Office of Innovation at UNICEF, *"we have not seen any other technological development with as much growth in recent years - or more potential to solve every conceivable problem - than Bitcoin, Ethereum and other applications of blockchain technology"*.[9] Yet *"few countries are showing support for adopting blockchains and crypto-currencies into their systems"*[10] explains Okonjo-Iweala, director general of the World Trade Organization, because it would make transparent

4 "Banking on Bitcoin: Nonprofit Success Stories Start to Emerge", Megan O'Neil, July 8, 2014, retrieved May 10 2022, https://www.philanthropy.com/article/banking-on-bitcoin-nonprofit-success-stories-start-to-emerge/
5 "The Bitcoin Water Trust is an exponential growth fund for clean water. Donate any amount of bitcoin and we'll hold it until at least 2025", https://www.charitywater.org/bitcoin#
6 15 November 2016 Michael Astor "UNICEF Is Investing In Tech Startups", https://www.unicef.org/innovation/stories/unicef-investing-tech-startups
7 UNICEF Programme Venture Fund, https://www.unicef.org/innovation/venturefund
8 "Blockchain applications in the United Nations system: towards a state of readiness", Report of the Joint Inspection Unit, Petru Dumitriu, JIU/REP/2020/7, July, 2020.
9 "UNICEF explains how Bitcoin donations help its cause" Shaury Malwa, April 9, 2021, https://cryptoslate.com/exclusive-unicef-explains-how-bitcoin-donations-help-its-cause/
10 "Blockchain can be particularly beneficial to women, says WTO Director General", Luc Jose Adjinacou, July 13, 2021, https://www.cointribune.com/en/blockchain-can-be-particularly-beneficial-to-women-says-wto-

practices that current recipients prefer to keep opaque. Okonjo-Iweala adds that while blockchain initiatives could be used to *"reduce poverty, empower women and give them easy access to financial markets",* the problem at the moment is that *"we are still a long way from realizing this vision".*[11]

However, NGOs are not the only ones to invest in the blockchain ecosystem, and many organizations, startups, companies, foundations, public/private partnerships and states are deploying innovative solutions in the fields of development aid, donations and development finance. Initiatives aimed at the local population with the help of volunteers, such as El-Zonte in El Salvador since 2019 or more recently **Kiveclair** in Goma in the Democratic Republic of Congo, are experimenting with *"giving satoshis**[12] *to help and educate on bitcoin"*.

These Bitcoin-based educational and development aid projects, like the more recent initiatives of **Bitcoin Lake** in Guatemala or **Bitcoin Beach Brazil**, represent a new model of development aid without any intermediaries between donors and recipients.

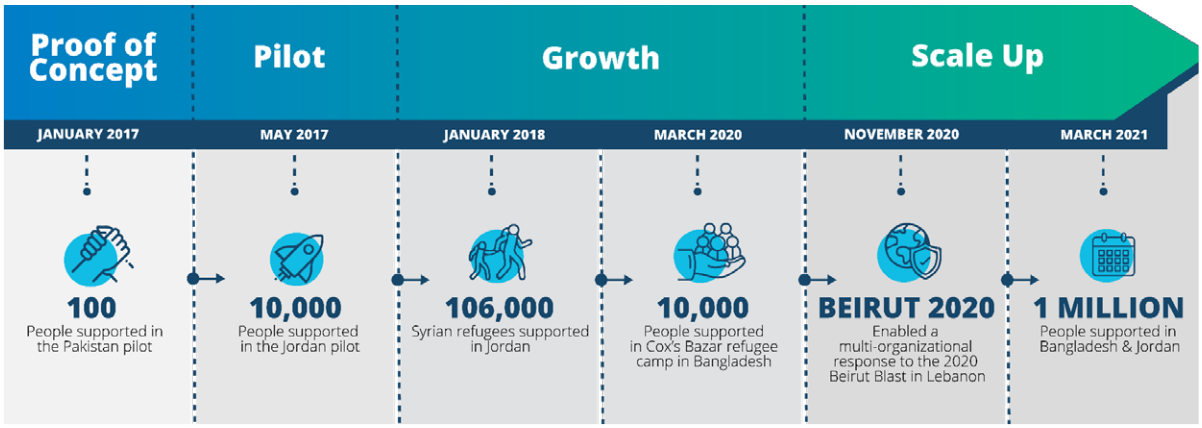
Development & Aid

In January 2017, the UN World Food Programme launched a proof of concept under the name **Building Blocks** in Sindh province, Pakistan, aimed at testing the use of a blockchain to authenticate and record humanitarian aid to beneficiaries while no longer going through a financial intermediary.

The program was later expanded *"to more than 100,000 aid recipients in Syrian refugee camps (in 2018), and an additional 46,000 people in Bangladesh (in 2020)"*[13] and was implemented in Beirut following the Lebanese capital's port explosion. According to the World Food Program, more than one million beneficiaries received $304 million in humanitarian aid saving $2.4 million in bank fees.

The United Nations was quick to want agencies to share their experience in order to explore other blockchain initiatives to be implemented in different contexts. A result was the money transfer program run through the Building Block platform by the UN entity for gender equality and women's empowerment, UN Women, tested in the Za'atari and Azraq refugee camps for women in Jordan in June 2019, and then in the Kakuma refugee camp in Kenya in 2020.

director-general/
11 *Ibid.*
12 Words marked with an asterisk are entered in the glossary at the end of the report. .
13 "Building Blocks Blockchain network for humanitarian assistance - Graduated Project", World Food Program, Retrieved May 10 2022, https://innovation.wfp.org/project/building-blocks



Building Blocks, Programme Alimentaire Mondial (PAM)
Source : https://innovation.wfp.org/project/building-blocks

The purpose of the pilot was to transfer money to two hundred women enrolled in incentive-based volunteer programs, also known as cash-for-work, at Oasis Centers for the Resilience and Empowerment of Women, set up in the Za'atari and Azraq refugee camps, beginning in June 2019.

The UN agency had already been using an iris recognition-based solution since 2016 to allow refugees in Jordan to authenticate themselves and buy food at camp supermarkets.

A "traditional" international cash transfer

Excerpt from: "To what extent can blockchain help development co-operation actors meet the 2030 Agenda?", OECD Development Co-operation Working Papers, May 7, 2021.[14]

In a normal cash transfer, the United Nations World Food Programme (WFP) provides refugee information to the local financial intermediary (often a bank), which opens and manages the recipients' bank accounts. WFP pays the bank the total amount of cash (deposited to the bank accounts) needed to purchase food. The bank informs the refugees that a bank account has been opened in their name, and provides them with a debit card or e-voucher. The refugees can then go to a local store and buy food. The bank validates the transactions, settles with the retailers at the end of

14 "To what extent can blockchain help development co-operation actors meet the 2030 Agenda?", Boiardi, P. et E. Stout (2021), OECD Development Co-operation Working Papers, n° 95, Éditions OCDE, Paris, https://doi.org/10.1787/11857cb5-en

each month, and provides a summary of the accounts to WFP.

The pilot, first expanded in 2020 to 467 women, was later expanded to 106,000 refugees in these camps, who can purchase food after scanning their iris at store checkouts. *"Through this system, the entitlements of cash-for-work participants are stored securely on the UN Women blockchain node. To access their funds - either in cash or to pay for goods - beneficiaries visit WFP-run supermarkets, where an iris scan identifies them and links them to their blockchain account"* the UN agency explains.

From a technical point of view, this program is based on an iris recognition solution developed by **Irisguard**, and implemented through a private Ethereum blockchain developed by Accenture and Microsoft as part of the American public-private consortium ID2020 and whose purpose is to provide an identity to all people who do not have one.

Founded in 2001, Irisguard is a British company that has created a biometric recognition solution based on iris scans. Its first major contract, in 2002, was for border control with the United Arab Emirates (UAE) to enable them to distinguish citizens from "deportees", i.e. workers deported from India, Pakistan and Bangladesh who try to enter the UAE with new documents.[15]

Since 2013, the company has been working with the United Nations, including the UN High Commissioner for Refugees (UNHCR), the World Food Programme (WFP) and national governments and non-governmental organizations (NGOs) around the world, as well as a large number of retail banks in the Middle East.

The company has developed an iris recognition system for the unbanked that has been deployed in a number of contexts including border control, ATMs, supermarket point-of-sale, and most recently, as part of authenticating a person with blockchain, replacing the private key with the iris scan. The programs deployed by these UN agencies rely on the use of a private Ethereum blockchain. The contractors tasked with implementing the solution are Accenture, Microsoft and Cairo Amman Bank, the four of which received some $220 million in contracts through the United Nations between 2014 and 2018 to create these pilots.

For Martin Lemberg-Pedersen, assistant professor of global refugee studies at the Department of Politics and Society at Aalborg University in Denmark, *"Programs such as the CCF partnership between UNHCR and Cairo Amman Bank-IrisGuard in Jordan and between UNHCR, WFP, and Accenture in the Zaatari and Azraq refugee camps are financializing information about the displaced. They are experimenting*

15 Martin Lemberg-Pedersen & Eman Haioty (2020) Re-assembling the surveillable refugee body in the era of data-craving, Citizenship Studies, 24:5, 607-624, DOI: 10.1080/13621025.2020.1784641

with converting displacement data into digital footprints, which can be used for verification and transactional purposes, and passed on to financial institutions".

The creation of proprietary, private IT systems based on biometric data collection, maintained by commercial companies in a near-zero regulatory environment raises countless questions with regard to the privacy of refugees and their human dignity. *"By engaging in these partnerships, humanitarian organizations such as UNHCR [United Nations High Commissioner for Refugees] are increasingly functioning as data brokers, accelerating the access of companies and financial institutions to the new windfall of the world's displaced populations"*[16] continues Martin Lemberg-Pedersen.

Regarding the use of biometrics in the humanitarian field, Oxfam's 2018 report "Biometrics in the Humanitarian Sector" also concluded that, on the specific use of aid recipients' biometric data, *"the potential risks to humanitarian agencies in holding large amounts of immutable biometric data - legal, operational, and reputational, combined with the potential risks to beneficiaries - far outweigh the potential benefits in almost every case"*.[17] The risks are real. This is evidenced by the recent attack on the International Committee of the Red Cross in January 2022,[18] which reported the theft of data on 500,000 people, including children separated from their families, prisoners, and refugees who have fled armed conflict or natural disasters. According to the International Committee of the Red Cross, *"the impact is global and the data comes from sixty Red Cross national offices, almost everywhere the NGO operates"*.

Another humanitarian aid initiative involving cash and voucher assistance was conducted by the Oxford Committee for Famine Relief, better known as Oxfam, a confederation of some 20 independent charities around the world. Cash and Voucher Assistance totaled $5.6 billion in 2019, doubling 2016 levels and accounting for 17.9 percent of total humanitarian assistance.[19]

The **Unblocked Cash** initiative is a cash and voucher assistance solution based on the Ethereum blockchain and **Celo** blockchain.[20]

16 Martin Lemberg-Pedersen & Eman Haioty (2020) Re-assembling the surveillable refugee body in the era of data-craving, Citizenship Studies, 24:5, 607-624, DOI: 10.1080/13621025.2020.1784641
17 "The Engine Room and Oxfam: Biometrics in the Humanitarian Sector", March, 2018. This report is available at https://www.theengineroom.org/
18 "Sophisticated cyber-attack targets Red Cross Red Crescent data on 500,000 people", International Committee of the Red-Cross, Retrieved May 10, 2022, https://www.icrc.org/en/document/sophisticated-cyber-attack-targets-red-cross-red-crescent-data-500000-people
19 "The State of the World's Cash 2020.", CALP, https://www.calpnetwork.org/publication/the-state-of-the-worlds-cash-2020-full-report/
20 See chapter "Peer-to-peer electronic cash systems and programmable money", "P2P payments and micro-payments".

Developed by Oxfam in partnership with Sempo[21] and ConsenSys,[22] the purpose of Unblocked Cash is to *"enable fast, efficient and transparent financial assistance for disaster relief".*[23] The project originated in 2019 in Vanuatu, a southern Pacific Ocean country of approximately 80 islands spanning 1,300 kilometers, which was hit by Tropical Cyclone Harold in April 2020 and whose Covid-19-related restrictions resulted in a significant reduction in income and livelihoods, particularly for people already in highly vulnerable situations.

The UnBlocked Cash initiative relies on three elements: 1. electronic "tap-and-pay" cards provided to beneficiaries, which they can use to purchase goods, 2. smartphones with the Sempo app pre-installed through which vendors receive payments, and 3. an online payment platform with which NGOs like Oxfam can disburse funds and monitor transactions remotely in real time.

Sidebar: Sempo, Ethereum, Bitcoin and Celo

Sempo is an Australian-based nonprofit co-founded by Nick Williams and Tristan Cole in July 2017, with the purpose of *"effectively distributing relief funds to at-risk communities around the world while increasing financial inclusion".*

From 2018 to 2021, Sempo relied exclusively on the Ethereum and Bitcoin blockchains, which, however, showed scalability issues, which Sempo had to solve by moving transactions to multiple sidechains*. To solve these scalability issues, Sempo has migrated its solution to the Celo blockchain, funded by a grant from the Celo Foundation. The open source[24] Celo project began in the fall of 2017 with the publication of their white paper, and an operational version launched in April 2020. Celo bills itself as a *"mobile-first blockchain that makes decentralized financial tools and services (DeFi) accessible to anyone with a cell phone".*[25]

The Celo blockchain protocol provides a platform from which to create "value-stabilized digital assets" such as Celo Dollars (cUSD) and Celo Euros (cEUR), stable coins allowing anyone to trade them quickly, at low cost, from any cell phone.

21 "Financial Inclusion for everyone", Sempo, retrieved May 10, 2022, https://withsempo.com/
22 "Unlock Web3", Consensys, retrieved May 10, 2022, https://consensys.net/
23 "OXFAM Introduces E-Vouchers as Aid Support to Disaster Affected Communities", Adorina Massing, Vanuatu Business Review, September 28, 2020, https://vbr.vu/news/oxfam-introduces-e-vouchers-as-aid-support-to-disaster-affected-communities/
24 Celo, Github, retrieved May 23, 2022, https://github.com/celo-org/celo-monorepo
25 "Welcome to Celo", Celo, retrieved May 23, 2022, https://docs.celo.org/

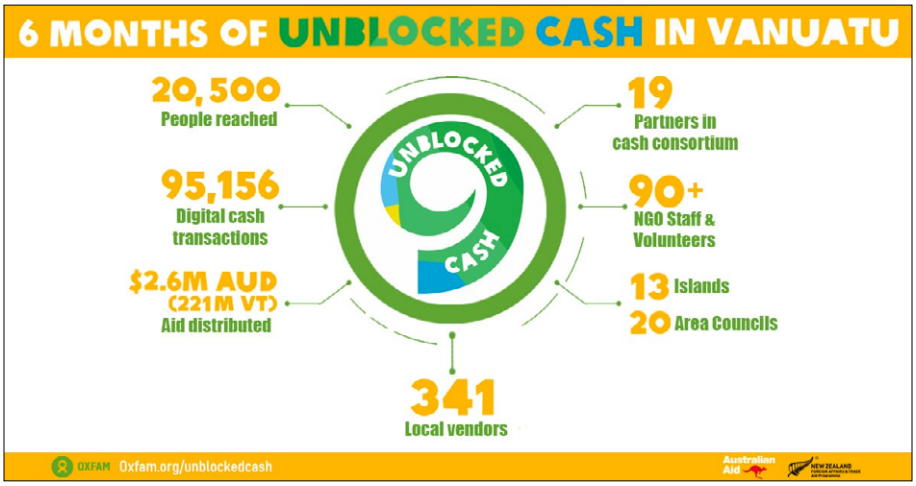
Celo consists of the following three elements:
1. an identity system,
2. a stability mechanism for stable value currencies, and
3. an incentive and governance system for the platform.

It is a proof-of-stake smart contract platform based on Ethereum. The Celo protocol is powered by a native digital asset called Celo Gold and all assets generated from Celo are ERC-20 compliant to facilitate token distribution via decentralized exchanges.

Since its launch in 2020, more than 1,000 projects have been developed on the Celo blockchain, enabling the issuance of digital currencies in about 100 countries around the world.

The UnBlocked Cash initiative brought together 19 different organizations, international and local NGOs, private sector companies and local government offices to provide cash assistance to the most vulnerable. According to Oxfam, more than 20,000 people living on 13 islands and 20 municipal councils in Vanuatu, or 13% of the total population in the target areas, have benefited from the program.

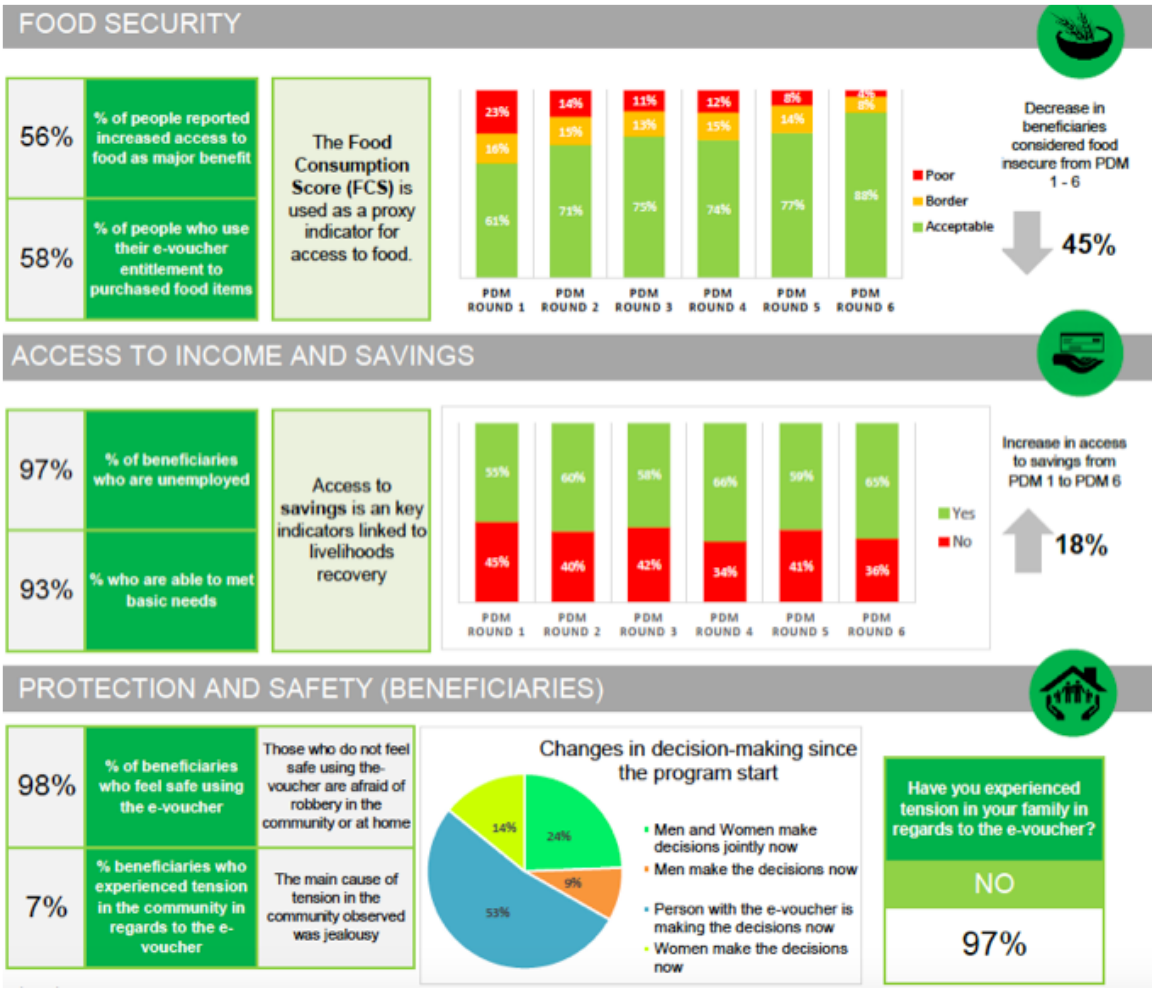
In a country like Vanatu, where there is no legislation on discrimination against women or sexual harassment, where 60% of women report having experienced physical and/or sexual violence from an intimate partner,[26] and where 80% of women work but have limited access to a banking institution,[27] the Unblocked Cash project also aims to empower them economically by targeting them as the primary beneficiaries of cash assistance. Oxfam implemented *"a comprehensive*



Unblocked Cash, Oxfam, Source : https://www.oxfam.org/fr/node/16213

26 "Vanuatu", UN Women - Asia and the Pacific, retrieved May 10, 2022, https://asiapacific.unwomen.org/en/countries/fiji/co/vanuatu

27 "Gender Equality and Gender-Based Violence Risk Mitigation in Cash and Voucher Assistance: Vanuatu Case study", Maja Tønning, Key Aid Consulting CARE, December 16, 2022, https://www.calpnetwork.org/publication/gender-equality-and-gender-based-violence-risk-mitigation-in-cash-and-voucher-assistance-vanuatu-case-study/



Unblocked Cash, Oxfam, Source : https://www.oxfam.org/fr/node/16213

outreach strategy to raise awareness of targeting priorities among community members, increase men's support for women as primary beneficiaries, and ultimately mitigate the risk of gender-based violence",[28] as the use of electronic coupons also avoided handling cash assistance.

A total of 3,744 families (households) were assisted through this program, 53% of the recipients being women.

Of the 341 vendors enrolled, 82% are in the informal economy and 42% are women. In the end, *"100,000 transactions worth more than US$2.5 million (more than VUV220 million) were spent with these 341 local vendors, ranging from large wholesale stores and supermarkets to local pharmacies and retail stores, market mothers and boat drivers".*[29]

28 "UnBlocked Cash — designing for gender equality", Oxfam UnBlocked Cash, February 17, 2021, https://medium.com/unblockedcash/unblocked-cash-designing-for-gender-equality-857276ef3195

29 "Lessons from Vanuatu— half a year of delivering relief aid on blockchain", Oxfam UnBlocked Cash, May 31, 2021, https://medium.com/unblockedcash/lessons-from-vanuatu-half-a-year-of-delivering-relief-aid-on-blockchain-ec326f81c688

According to Oxfam, NGOs have traditionally found it very difficult to include informal economy vendors in such programs, partly *"because of operational and financial constraints that made the payment process too long and unviable for small vendors"*.

End-to-End Traceability of Development Aid

One of the major challenges of development aid is also the multiplicity of donors, the diversity of channels through which financial flows are sent, the accumulation of transaction costs and the inability (or unwillingness) of recipient country institutions to track the use of funds.

According to an OECD report[30] published in 2021, *"sometimes the partner country's treasury may not even know the status of a disbursement or how much money is coming in, thus undermining the national investment budget planning process"*.[31]

With this in mind, KfW Entwicklungsbank, the German development bank, is developing **TruBudget**, for *Trusted Budget Expenditure Regime*, an open source application to *"increase the efficiency and traceability of funds by providing member states and donors with more transparency in resource allocation"*.

TruBudget is a private blockchain running on Multichain,[32] a blockchain framework for businesses.

30 Boiardi, P. et E. Stout (2021), To what extent can blockchain help development co-operation actors meet the 2030 Agenda?, OECD Development Co-operation Working Papers, n° 95, Éditions OCDE, Paris, https://doi.org/10.1787/11857cb5-en

31 "A blockchain-based workflow tool for an efficient and transparent project management", TruBudget, retrieved May 10, 2022, https://trubudget.net/

32 "Recent Q&A", Multichain, Retrieved May 10, 2022, https://www.multichain.com/qa/ & "Getting Started", TruBudget, Retrieved May 10, 2022, https://trubudget.net/docs/README/

The software permits the recording of the funding and spending processes corresponding to the projects implemented. The interest in using a distributed registry is to increase efficiency in the management of the public finances of the country receiving development aid and to make the use of these funds transparent.

A pilot was funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) in 2018 in Burkina Faso. As a result, the Burkina Faso government is developing its own version of TruBudget called SIGFE (Système d'Information de Gestion des Fonds Extérieurs) to manage donor-funded projects. In Ethiopia, TruBudget is being used to jointly manage KfW-funded projects in the field of higher education. Other pilots are still at the preparation stage: for example, Tunisia is developing the Caisse des Prêts et de Soutien des Collectivités Locales (CPSCL) with Smart Africa and the Gavi Vaccine Alliance, supported by the Bill and Melinda Gates Foundation, based on TruBuget. The Brazilian development bank BNDES also tested the scheme in 2018 to manage part of the Amazon Fund, particularly for individuals, but the project has been suspended for now.

While TruBudget is open source, it is deployed on a private blockchain where each stakeholder receives rights corresponding to their function and role in the project, allowing for the tracking of all contracting and procurement steps, as well as the release of payments in a short timeframe.

In the same vein, **Amply,**[33] conducted with UNICEF and the South African government, consisted of digitizing the management of a South African education program by recording on the Ethereum blockchain the kindergarten attendance of disadvantaged children and issuing tokens as proof of impact in exchange for government grants (see chapter "Peer-to-peer electronic cash system & Programmable Money" for more details).

Donation & Charities

Commission-free donation, donation without intermediaries, traceability of donations, NGOs accepting donations in crypto currencies or even financing donations via non-fungible tokens (NFTs): many entities are renewing the philanthropy and charity sector. The wave of non-fungible tokens (NFTs) since 2020 has also been used to fund social and environmental projects. We feature several of these in the "Web 3.0, Arts & Sciences" chapter.

The main concerns with charitable giving, when it goes through an intermediary, are the administrative costs, the transaction fees levied on donations, the potential corruption of intermediaries who manage funds and services, and the difficulty

33 "Impact Tokens: A blockchain-based solution for impact investing", David Uzsoki, Patrick Guerda, International Institute for Sustainable Development | https://www.iisd.org/system/files/publications/impact-tokens.pdf

for Non-Profit Organizations and other NGOs to track how the money is actually spent.

Decentralized Autonomous Organizations (DAO)

Founded in 2016 in Barcelona, Spain by Griff Green, Jordi Baylina and a few other members of the White Hat Group,[34] joined later that year by Vojtech Simetka and Grace Torrellas, **Giveth** is an open source platform created on the Ethereum blockchain whose purpose is *"to eliminate bureaucracy and enable nonprofit organizations to create a high level of transparency and accountability to donors".*[35] Giveth.io is currently deployed on the Ethereum network and the xDai network (see Finance Maker DAO Chapter). In 2017, an initial version of the decentralized giving app (DApp) launched on the Ethereum backbone and was redesigned and relaunched in 2021.

The Giveth DAO is a decentralized* autonomous organization that brings together donors, community leaders, campaign managers, campaign auditors, managers and auditors, and recipients, i.e. those who receive the funds.

The Giveth platform connects social good project owners and recipients of funds with donors.

As of May 2022, the platform had about 1,500 projects,[36] each with its specific goals, a section for updates, a donation summary showing the total amount given to the project, and a list of donors. For now, donations can only be made using crypto-currencies (xDAI or Ethereum) although credit card payment seems to be in the process of being implemented.

The platform is commission-free, with neither project owners nor donors subject to any platform fees. The only fees are those of the Ethereum blockchain when funds are moved. Giveth's DAO is entirely funded by donations.

In 2021, the community launched several services with the goal of creating *"an economy that is owned and governed by those who give".*[37] Launched on December 24, 2021, this GIVeconomy based on the GIV token is built around five areas :

- GIVbacks: A program that rewards people who donate to Giveth verified projects with GIV tokens. GIV also serves as the platform's governance token.
- GIVfarm: Rewards for cash providers and stakers who support the GIV token.
- GIVgarden: The decentralized governance platform of the

34 "We spoke to the vigilante hackers who stole $85 million in ether to save it", Jack Morse, Mashable, Jul 26 2017, https://mashable.com/article/ethereum-stolen-white-hat-group-rescued#ZPTC98wSEPOp
35 "Giveth", LinkedIn, retrieved May 10, 2022, https://www.linkedin.com/company/givethio/about/
36 GivEth : https://giveth.io/, retrieved May 12, 2022.
37 "Welcome to the GIVeconomy", Lauren, December 24, 2021, https://medium.com/giveth/welcome-to-the-giveconomy-b3e372da63dd Retrieved May 23, 2022.

GIVeconomy, where GIV holders can vote on proposals requesting funding from the DAO. GIVgarden relies on 1Hive (https://gardens.1hive.org/#/home) which is based on four components: 1. conviction voting for fund management: as of January 2022, the common pool, the amount of tokens available for funding proposals, was 32 million GIV, the equivalent of $15 million. 2. a voting application on the DAO, called TAO voting, which enables the execution of decisions on the blockchain. 3. a covenant, which defines the norms of behavior of the community on and off the blockchain, and 4. Celeste, a decentralized court to resolve disputes within the DAO.

- GIVstream: A continuous stream of GIVs that provides increasing governance power to participants in the GIVeconomy as it grows, until December 23, 2026.
- GIVdrop: A distribution to former Giveth participants and supporters designed to jumpstart the economy with value-aligned supporters.

One billion GIV tokens were issued at the launch of the GIVeconomy. 100 million GIV tokens are already liquid, and the remaining 900 million will be allocated to the GIVstream and released gradually over a 5-year period until December 23, 2026.

The Giveth initiative is complex at first glance. It combines a Decentralized Autonomous Organization, autonomous contracts, and a participatory financing platform. However, it takes up the challenge of connecting social utility project leaders with donors, without taking a commission, and managing the operation of a decentralized autonomous organization in a totally new format.

It is about involving donors, paid in GIV tokens, whose placement generates new tokens as rewards, the objective being to associate them with an ecosystem different from today's ecosystem that consists of making a donation to an association without follow-up or return as to the use of the funds.

Disintermediated Donation

Disintermediation is also a major component of the Kiveclair project, which showcases a new model of donation-based development aid, using a Lightning Network channel on Bitcoin (see box) to collect funds and send them directly to recipients.

Kiveclair's story began after lava flows from the Nyiragongo volcano near the city of Goma in the eastern Democratic Republic of Congo (DRC) became active in May 2021, causing panic in the city. By October 2021, thousands of volcano survivors were living in makeshift camps.

Lightning Network

The Lightning Network is a peer-to-peer payment protocol built as a second-layer application on top of the public Bitcoin blockchain. It was first described in a white paper by Joseph Poon and Thaddeus Dryja in 2015.

This second-layer application, built on the Bitcoin blockchain, allows two or more people to directly exchange bitcoins without transaction confirmation. These bitcoin transactions are done off-chain, meaning that they are not recorded on the Bitcoin blockchain. This makes them very fast, with virtually no fees, and also allows for the handling of very small amounts of money, on the scale of a satoshi*.

People using the Lightning Network can make as many transactions as they want. They can then decide to close this payment channel and the final balance each person has in their wallet is recorded on the bitcoin blockchain. (For more details, see the chapter "Peer-to-Peer Electronic Cash System and Programmable Money - Peer-to-Peer Payment and Micropayment").

On October 9, 2021, Gloire Wanzavelere, one of the four collaborators of the African media Chainglob based in Goma in the Kivu region of the Democratic Republic of Congo, launched a Lightning torch on Twitter. The principle is as follows: *"Whoever wants the torch can ask for it on Twitter of the last person who received it (who will only entrust it to a trusted relation). Each participant adds satoshis* (the amount they want) and transmits to the next recipient, via the Lightning Network, the whole amount collected".*[38]

This first Lightning torch allowed them to collect nearly 3 million Satoshis* and to help and train a dozen people in Bitcoin.[39] With this experience, the small team created the Kivéclair project, with the technical and logistical support of the Cercle du Coin, Indenodes, Nodl and JohnOnChain, and whose objective is *"to help about 50 families with satoshi and train them in the use of Bitcoin"*.

It is an online fundraising campaign, in Satoshis or Bitcoin, with the first level set at $25,000,[40] which will provide the beneficiaries with a cell phone on which a Bitcoin/Lightning network wallet is installed, through which each will receive twice a month, for six months, a donation of about $25 in satoshis*. The beneficiaries, people affected by the volcano and other marginalized

38 "La torche Lightning destinée aux sinistrés de l'éruption du volcan Nyiragongo est arrivée à destination", Jean Luc, October 25, 2021, Bitcoin.fr, https://bitcoin.fr/la-torche-lightning-destinee-aux-sinistres-de-leruption-du-volcan-nyiragongo-est-arrivee-a-destination/

39 "Aide via lightning : partager l'amour et la pilule orange", Gloire, December 9, 2021, https://chainglob.com/aide-via-lightning-partager-lamour-et-la-pilule-orange/

40 Kiveclair, Stage 0 - Help 50 People, retrieved May 2022, https://volcan.cust.nodl.cloud/btcpay/apps/25h57gEov2ZXJELV7THDUoLsSnwc/crowdfund

populations such as pygmies, will also participate in training to learn how to use the wallet. The bitcoins/satoshis will not be convertible into local currency, the idea being to circulate them in the local economy through businesses that accept bitcoin payments, also supported by Kiveclair.

The interest of such a project, like the Bitcoin Beach initiative in El Salvador[41] from which they drew inspiration, is to experiment with the use of Bitcoin both as a financial vehicle for disaster relief, with no intermediary between donors and beneficiaries, and as a tool for financial inclusion, through educational and technical support at the local level. The Bitcoin Beach initiative in El Salvador, which began in 2019, has attracted the interest of the Salvadoran government to the point of making it a legal currency on September 7, 2021, on par with the U.S. dollar.

Donations in Crypto for NGOs

Many major charities and international aid agencies have started accepting donations in crypto currencies. As early as November 2013, **BitGive**, a 501(c)(3) nonprofit registered in California in the United States and founded by Connie Gallippi, launched one of the first charitable campaigns, in favor of Save the Children, an NGO created in London in 1919 and which presents itself as *"the largest independent global movement working for children"*. It then raised funds in crypto-currencies to help the victims of Typhoon Haiyan that hit the Philippines in November 2013.

This was followed by numerous operations led by different NGOs such as Save the Children but also Code to Inspire, Heifer International or even Black Girls Code. In 2015, **BitGive** launched **GiveTrack**, a donation platform for nonprofit organizations, *"to provide transparency and accountability to donors by sharing financial information and direct project results in real time".*[42] GiveTrack is a crowd donation platform that allows donors to track their funds by project funded, and for recipients to report on its completion.

Several platforms provide a platform for nonprofits and charities to raise funds in bitcoin and other crypto-currencies, such as **The Giving Block** or **Engiven,** both created in 2018,

41 "Bitcoin Banking for Communities: Lessons Learned from Bitcoin Beach", Andrew, November 10, 2021, https://galoy.io/bitcoin-banking-for-communities-lessons-learned-from-el-zonte/
42 *Ibid.*

respectively in Washington and California in the United States. Engiven, for example, announced that in October 2021 it received a donation of $10 million in bitcoins from an undisclosed faith-based organization. The Giving Block allows more than 1,000 organizations to accept donations in crypto-currencies.

Fidelity Charitable[43] is a 501(c)(3) public charity registered in the U.S. since 1991 that has distributed $10.3 billion to charities in the U.S. and worldwide in 2021 alone. Crypto-currency donations in the same year accounted for $274 million, nearly four times more than in 2017, ($69 million), according to a company spokesperson cited by the Associated Press.[44]

UNICEF, Action Against Hunger: the list of NGOs accepting donations in crypto-currencies directly or through a platform is long.

Platforms that accept donations in crypto-currencies are becoming new intermediaries facilitating donation campaigns for NGOs, allowing the latter, within the same environment, to manage notably the diversity of donations (Engiven supports 42 different crypto-currencies), donation receipts, the holding (custody) of crypto-currencies and their conversion or not into fiat currency and into the banking system of the beneficiary NGO.

Does this mean that NGOs are wanting to adapt to their donors becoming younger? According to Pew Research,[45] 16% of Americans report having already invested, traded or used crypto-currencies, and that number rises to about four in ten American men and two in ten American women among those aged 18 to 29.

In France, a study published in February 2022 by the Association for the Development of Digital Assets (Adan) reports[46] that 8% of French people have also already invested in crypto-currencies, a figure that rises to 12% for those under 35.

43 “How the giving account works”, Fidelity Charitable, retrieved May 11, 2022, fidelitycharitable.org
44 “Charities see more crypto donations. Who is benefiting?” Haleluya Hadero, November 15, 2021, https://apnews.com/article/cryptocurrency-technology-business-bitcoin-philanthropy-34e629f4fcd40f950c49e159c24595fa
45 “16% of Americans say they have ever invested in, traded or used cryptocurrency” Andrew Perrin, PewResearch, November 11, 2021, https://www.pewresearch.org/fact-tank/2021/11/11/16-of-americans-say-they-have-ever-invested-in-traded-or-used-cryptocurrency/
46 “La crypto en France : structuration du secteur et adoption par le grand public”, ADAN, February 14, 2022, https://adan.eu/rapport/crypto-france-structuration-adoption

Donation via NFT

Non Fungible Tokens (NFTs*), associated with the fields of art and digital content, are becoming a new source of funding for projects with social and/or environmental dimensions. The first non-fungible tokens were created on the Bitcoin blockchain in 2012, with the Colored Coins proposed by Yoni Assia in a first article entitled *"bitcoin 2.X (aka Colored Bitcoin) - initial specs"*,[47] followed the same year by Meni Rosenfeld, author of *"Overview of Colored Coins*".[48]

A bitcoin is divisible to the eighth decimal place and is then called a Satoshi, in honor of the person or group of people who released the source code of the protocol in 2008. The first NFTs are thus Satoshis to which identification data have been attached, which characterize the uniqueness of the digital asset, making it lose its fungible character.

Indeed, the specificity of crypto-currencies is that they are fungible assets, i.e. any of these tokens can be exchanged for any other, whereas non-fungible tokens designate a unique digital asset. A non-fungible token is a unique and indivisible digital certificate, this uniqueness allowing it to certify the authenticity and ownership of original objects, including works of art, collectibles, physical or digital, as well as domain names, receivables and even real estate.

While the use of NFTs remained anecdotal until 2020, it is from the beginning of 2021 that they have been generating a media frenzy and hype from artists and the general public, especially when the international auction house Christie's proceeded to sell Beeple's digital work for $69.3 million in March 2021.[49] According to DappRadar,[50] NFT sales totaled $25 billion in 2021.

Since mid-2021 there has been a growth in what some call "NFT Philanthropy", a non-fungible token philanthropy that consists of putting creations of the mind (image, video, Gif, tweet, source code etc.) up for sale and donating the proceeds, in whole or in part, to a social or environmental cause.

Alex Wilson, co-founder of the crypto-currency fundraising platform The Giving Block estimates, in remarks reported by Cointelegraph,[51] that 30% of the platform's donations come from NFT initiatives, or $12 million.

47 "Bitcoin 2.X (aka Colored Bitcoin) – initial specs" March 27, 2012. Retrieved May 31, 2022, https://yoniassia.com/coloredbitcoin/
48 "Overview of Colored Coins", Meni Rosenfeld, December 4, 2012. Retrieved May 31, 2022, https://bitcoil.co.il/BitcoinX.pdf
49 "Non-Fungible Token, jetons non fongibles : quand le monde de l'art rencontre celui des blockchains", Jacques-André Fines Schlumberger, *La revue européenne des médias et du numérique*, N°57-58, https://la-rem.eu/2021/07/nft/
50 Dapp Radar, Retrieved May 31 2022, https://dappradar.com/
51 "NFT philanthropy demonstrates new ways of giving back", Rachel Wolfson, January 31, 2022, https://cointelegraph.com/news/nft-philanthropy-demonstrates-new-ways-of-giving-back

To celebrate its 75th anniversary, UNICEF conducted a sale of 1,000 NFTs, created by artist and scientist Nadieh Bremer, for a total of 235 ethers, the token of the public blockchain Ethereum, to support digital connectivity of schools in underserved communities, a project led by Giga.

The Giga project, created in 2019 by UNICEF and the International Telecommunication Union, is to: 1. map school connectivity[52] in developing countries, 2. connect all schools and communities around them, 3. fund network connectivity, and 4. create an ecosystem conducive to education and work[53] (see "Electronic Communication & Telecommunications" Chapter).

The programmable nature of NFTs* (see box "How an NFT works" in the chapter "Web 3.0, Arts & Sciences") also makes it possible to provide that for each transfer of an NFT, a part of the sale automatically goes to a cause.

It is already common to program a royalty clause in an NFT, which triggers the payment of a percentage or an amount fixed in advance with each resale of the token, a "resale right", ensuring that the creator receives income linked to the circulation of his or her work on the secondary market.

Finally, platforms have been created that claim to finance social and/or environmental causes, such as **NFTb**[54] or **Doingud,**[55] whose NFTs for sale include a percentage of the revenue allocated to a social cause. For example, the digital work "Yamamoto Nymph",[56] minted on the Polygon blockchain on December 24, 2021, was first put on sale at $250, with a distribution of proceeds, on this first transaction, of 87.5% for the creator, 10% for OutRight Action International, an international LGBT rights organization, and 2.5% for the platform. In June 2022, the NFT was put up for sale again, this time for $69,000, and if it resells on the secondary market, 10% of the proceeds will go to the creator and 2.5% will go back to OutRight Action International.

Finally, the sale of NFTs can be directly organized by collectives or groups of people gathering around a cause, such as **The Indestructible Donation**, launched by a collective of Ukrainian photographers, the sale of 40 photographs in the form of NFTs on the Opensea[57] platform and whose funds

52 "Mapping School Connectivity Globally", UNICEF, retrieved May 16 2022, https://projectconnect.unicef.org/map
53 "Bringing Connectivity to Schools in a Fair & Transparent Way Exploring where blockchain and Giga intersect", Christina Lomazzo, & Mehran Hydary, UNICEF.org, December 4, 2020, https://www.unicef.org/innovation/stories/blockchain-school-connectivity
54 "Our Mission", NFTb, retrieved June 27, 2022, https://nftb.io/charity/
55 "How it works", Doingud, retrieved June 27, 2022, https://doingud.com/
56 "Yamamoto Nymph", Doingud, retrieved June 27, 2022, https://doingud.com/creation/0xb335cc9dcdd441d703c8b96dc781499e3fd085c3000000000001?edition=1
57 "The Indestructible Donation", Open Sea, retrieved June 27, 2022, https://opensea.io/collection/the-indestructible-donation

will be donated to the Ukrainian non-governmental organization "Come back alive", created in May 2014 to help the Ukrainian army during the war in the Donbass, and reactivated since the invasion of Ukraine by Russia in 2022.

Donations from the sale of NFT and "NFT Philanthropy" are therefore an additional tool for organizations or communities of people to raise funds, and also renew the profile of their donors.

Humanitarian crisis

Crypto currencies are also used as remedies of last resort during liquidity crises, such as those deployed by Grassroot Economics in Kenya (see chapter "Peer-to-peer Electronic Cash System and Programmable Money - Community Inclusion Currency"), or during even deeper crises. In January 2021, The Intercept headlined "Hungry Afghans use crypto to avoid US sanctions, failing banks and the Taliban".

When the Taliban came to power in August 2021 and since the US withdrew its armed forces, Afghanistan has been facing a crisis, now humanitarian, that has received little coverage in the Western media.

The United States has seized the assets of the Afghan central bank, forbidden all money transfers to the country, disconnected the SWIFT system which allows international financial transactions, and stopped the delivery of cash by French and Polish companies, previously in charge of printing it.

As a result, nothing works in the country anymore. UNICEF estimates that *"3.2 million children are suffering from malnutrition and that more than a million of them are at immediate risk of dying of hunger"*.[58] For the United Nations, *"only 2% of the 40 million Afghans have enough to eat"*.

Code to Inspire, an NGO founded by Fereshteh Forough[59] in Herat, was teaching computer programming to young Afghan women. She explained to the Intercept[60] media that *"since September, we have been sending cash assistance, about $200 a month, for each family, because the majority of our students said their families had lost their jobs. They are the sole breadwinners of the family"*.

With banks refusing to transfer money, the NGO sends families BUSDs, a stable crypto-currency pegged to the U.S. dollar, allowing each family to receive the funds, converting them into Afghani,

58 "One million children at risk of dying from starvation in Afghanistan within weeks", UNICEF, December 202, https://www.unicef.ie/2021/12/02/one-million-children-at-risk-of-dying-from-starvation-in-afghanistan-within-weeks-unicef/
59 "Impoverished Afghan women are receiving emergency aid in crypto as the Taliban limits cash withdrawals and millions go hungry", Joshua Zitser, Business Insider, January 23, 2022, https://www.businessinsider.com/afghanistan-women-turn-to-cryptocurrency-to-feed-their-families-2022-1?r=US&IR=T
60 "Starving Afghans Use Crypto To Sidestep U.S. sanctions, failing banks, and the taliban", Lee Fang, The Intercept, January 19, 2022, https://theintercept.com/2022/01/19/crypto-afghanistan-sanctions-taliban/

the local Afghan currency, so they can *"pay for medical expenses, food and whatever else is needed"*.

Sanzar Kakar, an Afghan-American entrepreneur, created HesabPay[61] in 2019, an app that, among other things, allows people to send money converted into USDC, another stable crypto-currency indexed to the U.S. dollar. *"You can trade both ways, send it abroad or receive it abroad, without ever touching the banks, without touching the Afghan government or the Taliban"*[62] he explains.

61 "Guide Book", HesabPay, retrieved May 11, 2022, https://hesab.af/userGuide/en
62 "Starving Afghans Use Crypto To Sidestep U.S. sanctions, failing banks, and the taliban", Lee Fang, The Intercept, January 19, 2022, https://theintercept.com/2022/01/19/crypto-afghanistan-sanctions-taliban/

ISSUES AND QUESTIONS

While blockchain-based initiatives can increase the effectiveness of philanthropy and humanitarian aid, particularly by allowing it to reach audiences previously excluded from it, they nevertheless run up against the political problem of the dependence of so-called "developing" countries on the citizens and states of so-called "developed" countries. Indeed, journalist and essayist Naomi Klein described four years ago a new phenomenon that she first identified in Puerto Rico after the storm Maria, crypto-colonialism.[1]

The promise of blockchains to build a more horizontal world is indeed being instrumentalized by wealthy investors in order to test this technology at the scale of a state, according to ends that they have defined for themselves. Their motivations, according to Klein, are much less laudable than they appear. Indeed, the possibilities of tax optimization and the promise of making Puerto Rico "the Singapore of the Caribbean" tend to put their philanthropic ambitions into perspective.

This phenomenon is also visible in the areas mentioned in this chapter, where citizens of struggling countries depend on development aid and philanthropy to ensure their survival.

To this technophile model imported from the so-called developed countries, Naomi Klein opposes a completely different model, supported by several layers of Puerto Rican society, based on "sovereignty for the many" versus "secession for the few". How can blockchains contribute to this societal project, i.e. autonomous development in developing countries? How can communities reappropriate blockchains when they do not necessarily have the technical infrastructure necessary to use them? What supports can successful blockchain projects in the field of sustainable development develop to enable this re-appropriation?

Beyond crypto-colonialism, the system of direct aid for development has long raised fundamental questions: could this system be effective without the input of specialists who manage operations in the field?

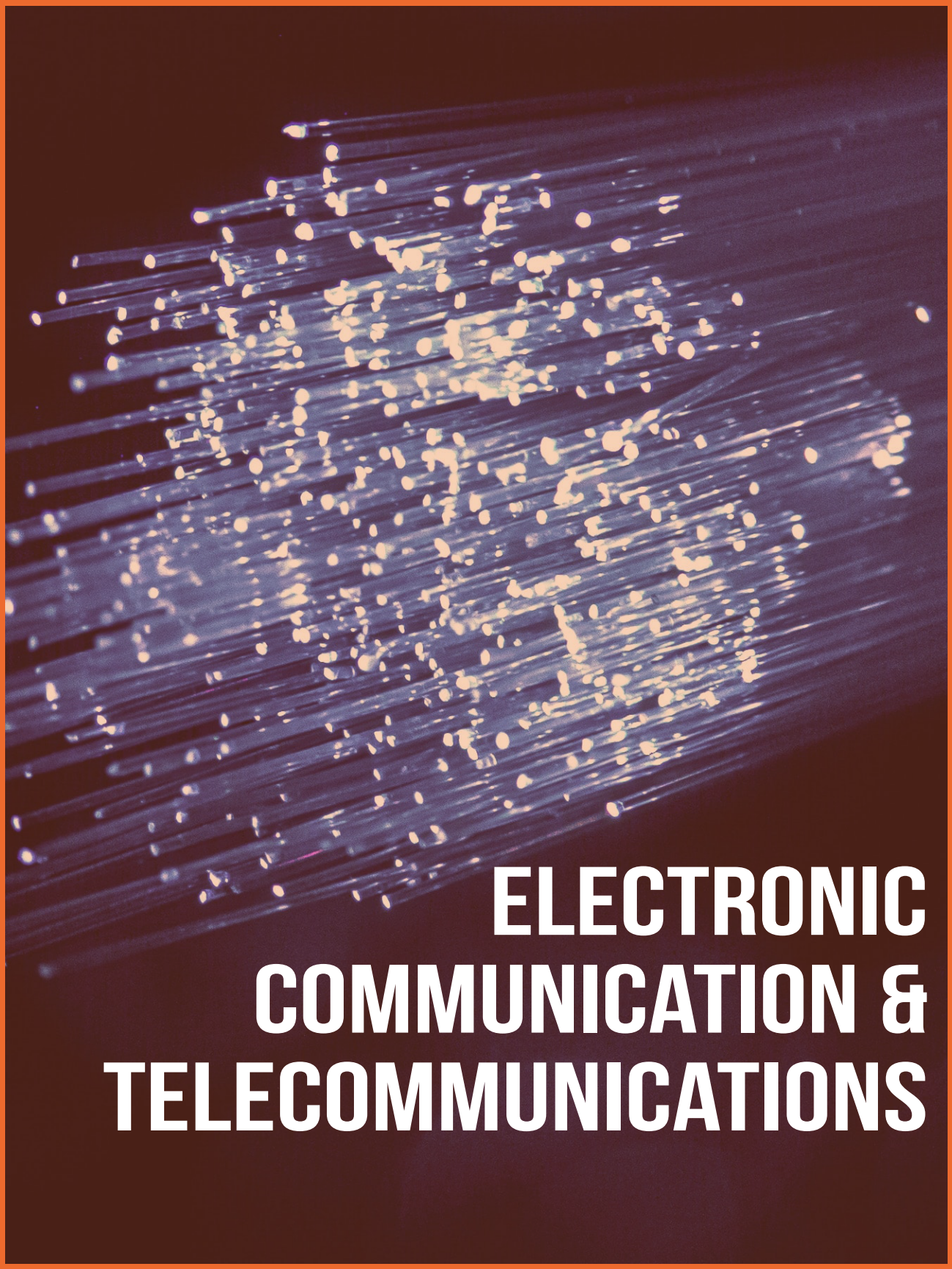
1 "The Battle for Paradise", Naomi Klein, ISBN 9781608463572, 2018, https://gdsnet.org/NaomiKleinBattleForParadisePart1.pdf

Doesn't this direct aid keep the beneficiaries in "permanent assistance" and in a model that relentlessly reproduces that of developed countries helping developing countries, raising the question of the "business of charity" as a whole?

Doesn't the technological contribution of blockchains, as soon as blockchains are private, directly expose itself to the criticisms long made by some researchers, such as Martin Lemberg-Pedersen, from the Department of Political Science at Aalborg University in Copenhagen, Denmark, and Eman Haioty, an independent researcher, who explain that *"the lack of common data protection standards between NGOs and states in the global South, as well as the legal immunity of UN institutions, creates what we can call 'outsourcing loopholes'. These allow technology companies to avoid direct liability when testing and researching new technologies on displaced populations".*[2] According to Mark Duffield, Professor Emeritus at the Global Insecurities Centre at the University of Bristol in England, *"complex humanitarian crises in the global South have become 'cyber-humanitarian laboratories' that function as feedback loops for private companies to test new technologies for the extraction, analysis and application of humanitarian displacement intelligence".*[3]

It is true that many blockchain projects *"still fit within traditional value chains and use the technology to progressively improve the transparency and efficiency"* of humanitarian aid, as Ronald M. Steyer, humanitarian aid and blockchain expert, explained in 2021.[4] The relatively spontaneous initiatives carried out in El Salvador, the Democratic Republic of Congo, Guatemala and Brazil should be followed closely, as they allow for the empowerment of local populations by switching from a monetary and humanitarian aid system in dollars, organized in silos, hierarchically from top to bottom, to an electronic money system in Satoshis*, operated in a peer-to-peer manner and usable locally, of which the interest consists largely in the capacity of populations to use the tools for themselves.

2 Martin Lemberg-Pedersen & Eman Haioty (2020): Re-assembling the surveillable refugee body in the era of data-craving, Citizenship Studies, DOI:10.1080/13621025.2020.1784641
3 *Ibid.*
4 "Blockchain in Aid & Philanthropy: State of affairs", Ronald Steyer, April 18, 2021, Retrieved May 23, 2022, https://medium.com/positiveblockchain/blockchain-in-aid-philanthropy-state-of-affairs-c0b1687833d1



ELECTRONIC COMMUNICATION & TELECOMMUNICATIONS

ELECTRONIC COMMUNICATION AND TELECOMMUNICATIONS

Number of projects in the directory: 35

Number of active projects: 29

Name of active projects: 3air ; Akash ; Althea ; BitClout ; Bitminutes ; Bitrefill ; Blockstack (formerly called OneName) ; Cajutel ; DAppNode ; Deeper Network ; Dent Wireless ; DFinity ; Filecoin ; Helium ; Holo ; HOPR ; KelVPN ; Kyve ; Maidsafe ; Mysterium Network ; NYM ; Orchid Labs ; RightMesh ; Skynet ; Stacks / Hiro;Substratum ; Syntropy ; Threefold ; World Mobile Token. *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

What if "*we radically changed the logic behind the organization of global networks? What if the users themselves were at the heart of the networks they use? What if blockchains were also used to build network infrastructures and protocols that were freer, more efficient, and better secured?"* asks journalist Cyril Fievet[1]. Indeed, the global telecommunications infrastructure is now centralized and based on the management of certain radio frequencies at the level of each state and a small number of national telecommunications operators who build the networks. Today, these networks "*underpin most of the applications on which our societies have become largely dependent in just a few decades*[2]. The so-called cellular networks of 1G or 5G operate internationally because they are standardized and regulated under the aegis of the International Telecommunication Union, the United Nations development agency specializing in information and communication technologies. Based in Geneva, Switzerland, the agency currently has 193 member states and 900 companies, including all of the world's telecom operators, universities, as well as international and regional organizations.

However, several blockchain projects imagine "decentralizing" Internet access, inventing distributed telecommunication networks, and ensuring that the principles of net neutrality and anonymity are

1 "Tomorrow, truly decentralized networks?", Cyril Fievet, Clubic, September 3, 2021, https://www.clubic.com/technologies-d-avenir/dossier-381429-demain-des-reseaux-vraiment-decentralises-.html
2 "Les fréquences, gestion d'une ressource-clé", Under the direction of François Rancy Foreword by Gilles Brégant Annales des Mines Série, Enjeux numériques, N°9, March 2020, https://imtech.wp.imt.fr/2020/03/13/les-frequences-gestion-dune-ressource-cle/

respected when using their services. But how do you decentralize a global network infrastructure? Because the reason why telecommunications *via* cellular networks have been regulated since 1865 is twofold. The radio frequency spectrum is a scarce resource. The frequencies that allow to establish a wireless electronic communication, on a cellular network, are only available in limited quantities at any given time. And on the other hand, these networks, from a material point of view, are very expensive to build.

From 1976 to 2020, there have been five generations of cellular networks: The first generation, known as 1G, dates from the 1980s and inaugurated the use of voice in mobile situations in the 1990s. The second generation, 2G, saw the development of SMS, the third generation, 3G, in the 2000s, inaugurated the use of the Web in a mobile situation, and ten years later, 4G has switched to voice over IP and increased speeds. The 5G, on the other hand, confirms the use of a global electronic communication network based on software virtualization of hardware functions. The history of cellular networks from 1976 to 2020 will therefore have consisted of the gradual abandonment of telephone technologies in favor of computer technologies to establish a communication henceforth electronic, the fifth generation networks being the consecration.

Thus, since 2013/2014, blockchain projects have swarmed in the areas of (1) Internet access, digital television and IP telephony, (2) low-speed networks dedicated to the Internet of Things, and (3) virtual private networks (VPN). Founded in 2013 in San Francisco, USA,

Helium is a peer-to-peer wireless network operating in the Internet of Things domain. In addition, even though the project is still in its infancy, the community around the Helium public blockchain is wondering about opportunities to adapt their decentralized network to (4) 5G.

What does 5G really change?

5G is not a simple improvement of the fourth-generation networks. Its implementation is *"*based on ***an IT architecture where network equipment is replaced by specialized servers and software."***

Specifically, the National Association of Research and Technology (NART[3]) explains that *"in a 5G network, many network functions will be virtualized, i.e., they will run as software (computing world),"* then providing the services of a *"private wireless network."* On this very high-speed "private wireless network," companies then become *"conceptually their own mobile operator on a clearly defined geographical area,"* without however becoming a telecommunications operator in the sense of the French

3 Created in 1953, the National Association for Research and Technology (ANRT) brings together public and private players in research and development (R&D) in France.

regulatory authority for electronic communications, posts, and press distribution (ARCEP[4]).

Because the data are then treated separately from those of the *"public network, the protection and confidentiality of the data related to the processes and production become theoretically total"*.

Or at least the value of the data escapes completely from the telecommunication operator and returns to the industrialist who manages this network himself, but also to his possible service providers, specialists of the data, and electronic communications.

Access to the Internet

Sustainable Development Goal 9, "*build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation*[5] ", states in target 9.c, which specifically addresses access to information and communication technologies, to "*significantly increase access to information and communication technologies and ensure that all people in the least developed countries have access to affordable Internet by 2020*[6]*".*

In 2019, UNICEF and the International Telecommunication Union launched **Giga**, with the goal of "*providing* [Internet] *connectivity to every school in the world.*" In 2020, 40% of the world's population, 3.2 billion people, cannot connect to the Internet, of which 1 billion are in South Asia, and 870 million in Africa.

The goals of Giga's project are to (1) map[7] the connectivity of schools in developing countries, (2) connect all schools and surrounding communities, (3) finance the network connection, and (4) create an ecosystem that supports education and work[8] .

4 Created by the law of July 26, 1996, the Autorité de régulation des communications électroniques, des postes et de la distribution de la presse (ARCEP) is an independent French administrative authority responsible for regulating electronic and postal communications and press distribution.
5 Goal 9: Build resilient infrastructure, promote sustainable industrialization that benefits all, and foster innovation https://www.un.org/sustainabledevelopment/fr/infrastructure/
6 *Ibid*.
7 "Mapping School Connectivity Globally", UNICEF, retrieved May 16, 2022, https://projectconnect.unicef.org/map
8 "Bringing Connectivity to Schools in a Fair & Transparent Way Exploring where blockchain and Giga intersect", Christina Lomazzo, & Mehran Hydary, UNICEF.org, December 4, 2020, https://www.unicef.org/innovation/stories/blockchain-school-connectivity

To carry out this mapping, Giga is testing school connectivity through a real-time tracking system whose information is stored in a public blockchain to "*reduce the possibility that the information has been falsified by the school, the ISP, or another third party.*"

By 2021, one million of the six million schools targeted by the project have been mapped. They are spread across 41 countries, including Kenya, Rwanda, Sierra Leone, Kyrgyzstan, Kazakhstan, Uzbekistan, El Salvador, Honduras, and Brazil. 44% of the schools mapped do not have an Internet connection. Secondly, when a school is connected to the Internet, Giga ensures that connectivity is maintained, in particular through autonomous contracts* that allow "*managing the relationship, agreement compliance, and execution with the Internet service provider*[9] " and prevent, for example, when a school is not connected for more than 10 days.

Under certain conditions, the *smart contract* will be* able to trigger payment to the local Internet Service Provider (ISP) when it fails. Giga will also be able to offer individuals "*the possibility of establishing a reputation across borders in a decentralized manner*," notably through the provision of digital certificates[10] attesting to education, thus making it possible to "*unlock access to new services such as banking services or informal identification*." (see chapter "Employment & Training").

In particular, Giga is working on this topic with the blockchain company OS City, founded in 2016 in Mexico City, which deploys distributed utility infrastructure for governments.

To finance part of the investment required to set up Giga, Unicef has launched since January 2022, in collaboration with Snowcrash Labs[11] , a collection of non-fungible tokens (NFT*) entitled "Patchwork Kingdoms[12]", each representing a school.

The sale of NFTs serves to publicize the project while raising funds to support the connectivity program.

Source [12]

9 *Ibid*.
10 "Exploring Blockchain for certification", UNICEF, retrieved May 17, 2022, https://certificates.unicef.io/
11 "Introducing birds of Solis", Snowcrash, retrieved July 8, 2022, https://snowcrash.com/
12 "Patchwork Kingdoms", GIGA, retrieved July 8, 2022, https://www.patchwork-kingdoms.com/

The *startup* **3air** is interested in the problem of Internet access in Africa, especially because network infrastructures require much higher investments than they are funded. Their idea is to replace the implementation of a wired access network that arrives at everyone's home with an Internet network sent *via* a transmitting station and received using satellite dishes.

The transmitting station, called "K3 last mile", is a patented technology owned by the Swiss telecommunications operator K3 Telecom. A station would be able to provide an Internet connection of up to 1Gb/s up to 50 km away and accommodate up to 15,000 Internet users per station.

The use of a blockchain would allow for the management of users' digital identities, transactions without going through a banking institution, and a number of services, including "*customer loyalty and sponsorship, governance and community building, microcredit, Internet of Things, and other important telecom-oriented features.*" 3air was to be built on the **Cardano** public blockchain and use **Atala Prism's** decentralized identity system. But faced with a shortage of technical skills, the company chose to migrate to another blockchain, **SKALE network**, which attempts to improve the security and decentralization of Ethereum-based applications.

The physical network infrastructure has already been deployed in the United States, Canada, Spain, Czech Republic, Slovenia, Mauritania, Liberia, and Sierra Leone, one of the poorest countries in Africa. An initial token offering (ICO), aimed at accelerating the company's development, particularly in other African countries, has been postponed several times.

The platform developed by 3air targets local Internet Service Providers (ISPs) and telecom operators by offering them a turnkey system for signing up new customers, tracking subscription status, and payment solutions *via* blockchain. 3air's system simplifies service management and automates time-consuming administrative procedures. It also relies on a decentralized identity management system that prevents the exploitation of users' personal data without their knowledge (see chapter "Identity and ownership").

This initiative is particularly targeted at countries that do not have a functioning banking system or developed network infrastructure. 3air also imagines being able to establish and track user credit scores that could then be used to set up lending systems within or even outside the[13] platform. The blockchain infrastructure is used to allow an ISP or other operator to manage new customers, who will have to generate a decentralized ID with the operator, which, however, seems to exclude people who do not

13 "White paper", 3air, retrieved June 8, 2022, https://docs.3air.io/pdf/3air_whitepaper.pdf

have proof of their identity (see chapter "Identity and ownership").

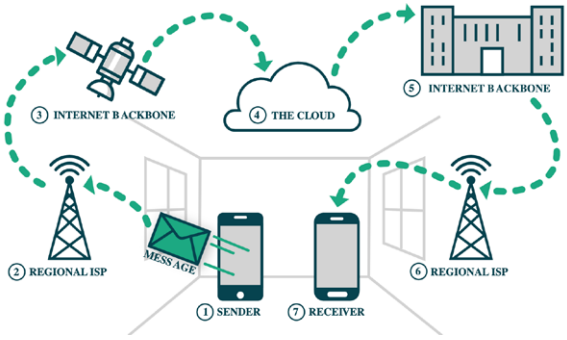
Founded in Canada in 2014 but ceasing operations in 2019, **RightMesh** billed itself as a blockchain company that "*makes last-mile connectivity affordable by using smartphones to create mobile mesh networks*."

In telecommunications, the "last mile" refers to the gap between an Internet service provider's (ISP) infrastructure and a customer's home or workplace. Incubated from 2014 to 2018 by Canadian company Left, RightMesh AG is now based in Zug, Switzerland, and appears to be shuttered.

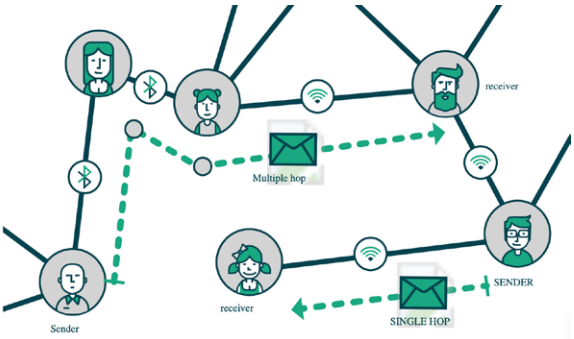
RightMesh has been working on a project in Bangladesh to form mobile mesh networks by establishing and managing device-to-device connections between Android phones or IoT devices*.

The connections are formed using technologies inherent in the device, such as Bluetooth, Wi-Fi, and Wi-Fi Direct.

RightMesh's proposal was as follows:



Réseau traditionnel[14]



Réseau RightMesh[15]

Once a device was connected to the mesh network, it could send and receive data in one of two ways: either in a single "hop" directly from one device to another, or in a "multi-hop" mode, with data being transferred through many devices until it reached its destination point.

This method would also have allowed for offline message delivery over greater distances. Tests and pilot projects were conducted in Bangladesh between 2018 and 2020 before the project came to a halt[16].

14 "Rightmesh ", Rightmesh, Medium, retrieved May 17, 2022, https://medium.com/@RightMesh
15 *Ibid.*
16 *Ibid.*

Althea, a U.S. company based in Oregon, bills itself in its 2017 white paper[17] as an *incentivized* mesh network protocol. It is an alternative Internet service provider that focuses on the "last mile" problem (see *above*). The areas that do not offer an Internet connection are called white zones.

Althea Network uses blockchain technology to "*decouple the service and infrastructure layers of Internet provision, giving end users the ability to share revenue by hosting the network infrastructure.*" They are thus implementing a mesh network that relies on routers purchased by individuals, who become network operators.

A mesh network is a network topology where all hosts are connected in a peer-to-peer fashion, without a central control point, and thus transfer incoming and outgoing data. Althea's local networks are thus made up of nodes owned by the people who use them, and the networks are locally managed and governed by the community of their users. These routers "*pay each other for bandwidth using payment channels in crypto-assets*[18]".

On top of this network of routers and data transfer, Althea is building a system that allows consumers to pay for Internet access. The system is built on the **xDai** blockchain, a second-tier (layer 2) blockchain on the Ethereum blockchain, allowing microtransactions to take place at virtually no cost.

Already deployed locally in the United States, Althea, in partnership with Hub Advanced Networks, announced in December 2021 to build this type of mesh network on the island of Puerto Rico to provide Internet connectivity in remote areas.

ThreeFold[19] , established in 2017, is a Peer-To-Peer and autonomous Internet Grid infrastructure that does not use the traditional TCP/IP protocols, which are used to transfer data over the Internet.

The network infrastructure is based, as of June 2022[20] , on 3,100 nodes, called 3Nodes. These servers run on an *open-source* operating system called Zero-OS and are managed by independent individuals or organizations called ThreeFold Farmers ("*Farmers*"); there is even a guide[21] for anyone to create 3Node server simply.

Each 3Node provides three primitive functions of storage capacity, compute capacity (in the form of containers), and network capacity (for running network services) and are paid in tokens (TFTs) based on their participation in

17 Althea, "White paper", Github, retrieved July 8, 2022, https://github.com/althea-net/althea-whitepaper/blob/master/whitepaper.pdf
18 "Althea Network", Althea, retrieved July 8, 2022, https://www.althea.net/
19 "Learn How to build the people's Internet", Threefold, retrieved May 17, 2022, https://library.threefold.me/info/threefold#/
20 "ThreeFold Explorer", Threefold, retrieved July 8, 2022, https://explorer.threefold.io/all
21 DIY Nodes Guide, Threefold, retrieved July 8, 2022, https://forum.threefold.io/t/diy-nodes-guide/837

the network in terms of capacity (compute, storage, network). ThreeFold Farmers generate tokens called TFTs that they receive in proportion to their participation in the infrastructure. Finally, users spend TFT tokens to use compute, storage, and network capacity in a modular fashion on a distributed blockchain ledger.

Created in 2017 on **ThreeFold**'s **Rivine** blockchain, TFT is a utility token that thus allows its holders to use the ThreeFold Grid's internet capacity to store their data and create applications.

Since ThreeFold version 3.0, updated in August 2021, all storage, compute and network capacity activity, billing, usage tracking, identity, and provisioning are managed on the Stellar public blockchain through the TFT token. As of June 2022, ThreeFold thus offers 84 Petabytes of online storage capacity spread across 80 countries worldwide and secured *via* 1,230 ThreeFold Farmers.

Syntropy, established in February 2018, also bills itself as "*an open project providing next-generation connectivity technology for the Internet*," powered by the NOIA token. The white paper describes the project as "*an ecosystem and platform consisting of open source software that optimizes and encrypts Internet traffic using modern encryption libraries, encrypted relays, backed by a blockchain-based distributed ledger. Collectively, these technologies serve as the foundation for a secure network and sharing economy on top of the existing public Internet services*[22] ."

Internet of Things (and 5G)

The Internet of Things refers to this paradigm where the Internet network and the computational capabilities of the computer (transmitting, receiving, processing data) are spread in objects, places, and physical environments. This network connectivity finds applications in various domains, including housing, agriculture, health, transportation, and energy.

While the cellular networks of telecommunication operators offer increasingly fast but expensive speeds, other types of so-called low-speed networks have been developed and are exclusively dedicated to the communication of objects *via the* Internet. These Low *Power Wide Area Networks (*LPWAN) are used as networks for the Internet of Things (IoT) and in machine-to-machine communication.

They are based on Ultra Narrow Band (UNB) frequencies that are not regulated by the International Telecommunications Union and carry small amounts of data (a few KB) over long distances (a few tens of kilometers) while requiring little energy[23] .

22 "A business case for an Internet Blockchain," William B. Norton, June 2, 2021, Syntropy Net, https://www.syntropynet.com/docs/Internetblockchain
23 In 2009, a Sigfox device consumes 1,000 times less energy than a GSM device.

Founded in 2013 by Napster alumni Shawn Fanning, Amir Haleem, and Sean Carey, **Helium** is a decentralized wireless low-bandwidth *network* for the Internet of Things market.

Their white paper, published in November 2018, explains that they want to create a network to allow "*devices anywhere in the world to wirelessly connect to the Internet and geolocate without the need for power-hungry satellite tracking tools or expensive cellular plans.*"

Helium has developed the Helium Wireless Protocol, WHIP, a "*secure, bi-directional, long-range, low-power wireless network protocol compatible with a wide range of existing radio transceivers operating in the unlicensed frequency spectrum.*" It is a two-way data transfer system between wireless devices and the Internet *via* a network of independent providers where (1) devices pay to send and receive data over the Internet and geolocate themselves, (2) miners earn tokens to provide network coverage, and (3) miners earn fees on transactions, and to validate the integrity of the Helium network.

The distributed network relies on "*Proof of Coverage*", where HNT tokens are issued as rewards to participants operating network access points. From December 2021 to June 2022, the network grew from 417,000 to 846,551[24] hotspots in 176 countries, which can be tracked in real-time at http://explorer.helium.com/hotspots.

On April 14, 2021, the Helium community voted[25] to work on an evolution of the network that would, in the long run, **build a decentralized 5G network on the same principle**. In August 2021, Helium raised $111 million in a token sale led by Andreessen Horowitz, a U.S. venture capital fund.

To our knowledge, this is the first blockchain project to challenge the industrial and centralized nature of the new data operators made possible by 5G, a colossal market that is also attracting the covetousness of the world's top three cloud service providers, Amazon, Microsoft and Google, known as hyperscalers[26] .

24 "DISH First Major Carrier to Bring Helium 5G to the People", Amir Haleem, Helium, October 26, 2021, helium.com

25 HIP 27, an "*economic mechanism to support new wireless protocols on the Helium network, starting with LTE and 5G in the Citizens broadband radio service (CBRS)# spectrum band*. According to the Helium developers, "*the data pricing and proof-of-coverage algorithm and business model that works well for LoRaWAN is not ideally suited for other wireless protocols such as 5G, LTE, Wi-Fi, etc.*"

26 Because they would become both key resources of 5G and "owners" of the data of their "free services" broadcast on the web, Google.com, Facebook, Amazon, these hyperscalers should not be *"considered as competitors like any other,"* says the National Association of Research and Technology (ANRT).

Helium's technical ecosystem (from the white paper "Helium A Decentralized Wireless Network").

The Helium network is a decentralized wireless network built around WHIP on a specially designed blockchain, with a native token, the NHT.

- The devices come in the form of hardware containing a radio chip and WHIP-enabled firmware and spend tokens by paying miners to send data to and from the Internet.

- Miners earn tokens by providing wireless network coverage through specially designed hardware to bridge WHIP and routers, which are Internet applications.

- Devices store their private keys in storage hardware and their public keys in the blockchain. Miners join the network by asserting their location via satellite, a special type of transaction in the blockchain, and depositing a token.

- Miners specify the price they are willing to accept for data transport and proof-of-location services, and routers specify the price they are willing to pay for their device data. Miners are paid once they have proven that they have delivered the data to the specified router in the device.

- Miners participate in the creation of new blocks in the blockchain by being elected *via* the *asynchronous Byzantine Fault Tolerance* (aBFT*) consensus mechanism. They are then part of the consensus group.

- Elected miners are rewarded with new protocol tokens when new blocks are created.

- The likelihood of a miner being elected to the consensus group at any given time is based on the quality of the wireless network coverage it provides.

- The blockchain uses "proof-of-coverage" (PoC) to ensure that miners honestly represent the coverage of the wireless network they are creating.

From "Helium: A Decentralized Wireless Network" Amir Haleem, Andrew Allen, Andrew Thompson, Marc Nijdam, Rahul Garg Helium Systems, Inc. release 0.4.2 2018-11-14 http://whitepaper.helium.com/

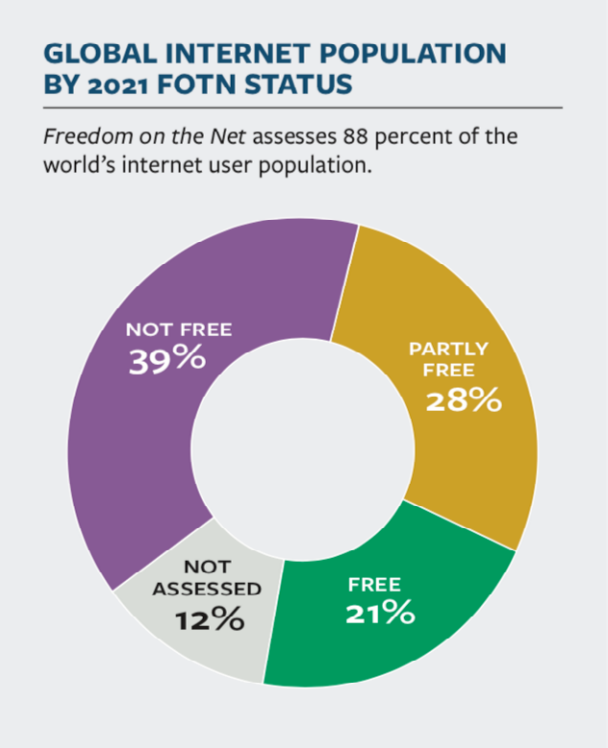
Decentralized virtual private network

The Internet is a common good, available and open to all. Net neutrality is the IT principle that aims to exclude any discrimination with respect to the source, destination, or content of information transmitted over the network to ensure that users will not face any Internet traffic management that would limit or enhance their access to applications and services distributed over the network.

In 2009, Benjamin Bayart, an activist for fundamental freedoms in the information society and a French engineer, proposed four principles essential to net neutrality[27] : (1) transmission of data by operators without examining its content, (2) transmission of data without taking into account the source or destination of the data, (3) transmission of data without privileging a communication protocol, and (4) transmission of data without altering its content.

According to the non-governmental organization Freedom House, "*Internet freedom around the world has declined for 11th consecutive years, with the greatest deterioration in Myanmar, Belarus and Uganda*".

The NGO recently released its annual report on Internet freedom and revealed that of the "*70 countries covered in the report, 48 countries - which account for 88% of the world's Internet users - have imposed new rules on technology companies regarding content, data or competition in the past year*[28]".



Many Internet users, especially in countries subject to Internet censorship and filtering, use a virtual private network to connect to information sources or use services prohibited by their government.

27 "Political roundtable: Net neutrality, freedom of expression on the Internet...the Telecom Package and the HADOPI law", Benjamin Bayart, April, July 9, 2009. https://www.april.org/transcription-table-ronde-politique-des-rmll-2009

28 "Freedom on the Net 2021", Grant Baker, Cathryn Grothe, Amy Slipowitz, Manisha Vepa, Kian Vesteinsson, and Tessa Weal, Freedom House, 2021, https://freedomhouse.org/sites/default/files/2021-09/FOTN_2021_Complete_Booklet_09162021_FINAL_UPDATED.pdf

A Virtual Private Network (VPN) is software installed on the user's computer or smartphone that redirects Internet traffic through a secure tunnel, masking the user's IP address and encrypting data. Using a VPN has the advantage of avoiding censorship by an Internet Service Provider (ISP) or by an authoritarian state[29] .

With hundreds of free and paid VPN software offerings on the market, it's hard to make an informed choice about which service to use, especially since many scandals have marred the reputation of these software products.

According to a 2020 study conducted by TheBestVPN[30] , of the 115 VPNs surveyed, 26 collected personally identifiable data, including IP addresses, locations, bandwidth data, and connection timestamps. More intriguingly, the business model of some free VPNs, touted to provide a secure and anonymous connection, actually relies on selling their users' personal data.

Because a VPN relies on a central operator to manage the servers on which data travels, blockchain projects have developed to replace it with a distributed architecture to technically ensure that the network connection is secure and protected. Werner Vermaak, a reporter for CryptoSlate, defines a decentralized VPN as "a *secure Internet connection managed by a network of nodes, which receive compensation for maintaining their services and ensuring the security of the network. Decentralized VPNs work differently than regular VPN services, as they normally do not have a central provider that manages the forwarding of Internet traffic*[31]."

Decentralized VPNs work through decentralized applications (dApps)*, which allow the network to be secure and the user, from their web browser, to select the nodes through which their connection will be encrypted.

Nym, Mysterium Network, **Deeper Network**, **HOPR**[32] , **KelVPN,** or even **Orchid Labs** are some of these decentralized VPNs. Mysterium Network, founded in 2017, claims to have grown from about 6,500 active nodes in November 2021 to more than 20,000 active nodes in June 2022, spread across more than 120 countries, with monthly data traffic exceeding 700 Terabytes and almost 67,000 daily sessions[33] .

29 According to the association, FreedomHouse.org, the following countries fully filter Internet connections entering and leaving their borders: China, Iran, Myanmar, Cuba, Vietnam, Saudi Arabia, Pakistan, Egypt, Ethiopia, United Arab Emirates, Uzbekistan, Venezuela, Russia, Bahrain, Belarus, Kazakhstan, Sudan, Turkey, Azerbaijan, Thailand, Rwanda.
30 "100+ VPN Logging Policies Debunked", Rob Mardisalu, TheBestVPN, January 6, 2020, https://thebestvpn.com/
31 "VPNs for data privacy", Erner Vermaak, CryptoSlate, April 18, 2021, https://cryptoslate.com/
32 HOPR, created in Zurich, Switzerland in 2020, is presented as "*a general network layer protocol to allow users to exchange data privately, in the same vein as Tor (the onion router) or a virtual private network (VPN)* "#. The network is still in the testing phase.
33 "Mysterium makes the Internet blind to borders", Mysterium, retrieved May 17, 2022, https://www.

Deeper Network, founded in 2019 in Santa Clara, USA, claims 65,000 nodes in over 200 countries[34].

Orchid Labs, founded[35] in 2017 in San Francisco, USA, bills itself as "*a decentralized and open system for anonymous communication and Virtual Private Networking (VPN), including a bandwidth marketplace where node providers stake a digital currency to advertise their services using the Ethereum blockchain and receive payment in OXT (Orchid's native crypto asset).*"

Orchids Labs has created a decentralized VPN ecosystem based on (1) a computer and smartphone app, available for free to the user, (2) a token called OXT, (3) a system of Orchid accounts to ensure their privacy, (4) a nano-payment system, (5) a system of nodes, and (6) a staking system*.

The OXT token, an ERC-20* token on the Ethereum blockchain, serves as a digital currency between bandwidth providers and users. The bandwidth providers, all independent of each other, are the nodes of the network.

The system is open so that anyone can operate an Orchid node, provided they have OXT tokens. Indeed, the Orchid blockchain relies on proof of ownership to secure transactions on the network. The more OXT and nodes a user holds, the greater the chances of being rewarded for validating blocks of transactions on the network.
On the other hand, the user pays, on a "nanopayment" scale, in OXT tokens or in another supported crypto-asset, for the time spent using the secure Internet connection.

Since the payment is time-based, Orchid uses a payment architecture called "*probabilistic nanopayments for packet network payments*[36] ". These nanopayments are operated on the Orchid blockchain to avoid Ethereum network congestion and fees.

The minimum amount to start using Orchid Labs' decentralized VPN is one dollar. Another feature allows users to purchase "Orchid credits" in fiat currency, these OXT tokens can then no longer be withdrawn and converted elsewhere, but only spent with network providers. The marketplace where supply and demand meet is decentralized and operates on a peer-to-peer basis, which guarantees the user the efficiency of the service.

Another example, the startup **NYM**, based in Neuchâtel, Switzerland, has also been developing since 2018,

mysterium.network/
34 "Deeper Network Basic Mining 2.0 + Mining updates for Genesis and Basic Mining, Deeper Network May 13 https://deeper-network.medium.com/deeper-network-basic-mining-2-0-mining-updates-for-genesis-and-basic-mining-2ec2f112cfd4
35 By Dr. Steven Waterhouse, Jay Freeman, Brian J. Fox, Gustav Simonsson, and Stephen Bell.
36 "Introducing Nanopayments" Orchid, October 9, 2019, https://medium.com/orchid-labs

a "*confidential, open source, decentralized and permissionless*" network infrastructure by providing a so-called full-stack privacy system, which can be translated as "turnkey". For its founders, privacy on the Internet is "*undermined by pervasive data collection and centralized monopolies, which prevents the emergence of innovative services and platforms*[37]".

To address this, NYM's infrastructure allows "*other applications, services or blockchains to provide their users with strong metadata protection, both at the network level (mixnet), and at the application level (anonymous credentials) without the need to build privacy from scratch*."

Nym is a top-level network that supports the functions of accessing online services for use by application providers and their users. To protect the data that flows over the public Internet, the Nym network is composed of a decentralized mixnet (a network of mixing nodes), inspired by the 1980s work of cypherpunk David Chaum.

On a mixnet, connection data is grouped into packets, successively encrypted, and then transferred from node to node (*mix nodes*) where each node removes a layer of encryption until the last one delivers the message to its recipient.

In this way, the connections that are made on the network are completely anonymous, even for the biggest attackers, who are able to monitor the network in its entirety.

The Nym network has 472 nodes for 13 gateways and 27 validators in June 2022[38] . The technical operation of the network is similar to that of the Tor network, an open source project registered in 2006 but imagined in the 1990s, notably under the impetus of the American Naval Research Laboratory (NRL), which was looking for a way to "*route traffic through several servers and encrypt it at each stage*[39] " and thus protect its communications on the emerging Internet.

To use the Tor network, a person downloads the eponymous browser[40] for free, and traffic passes through a minimum of three relay nodes before reaching a final exit node. While Tor is based on a network where the nodes to route traffic are volunteers, the beauty of decentralized VPNs is that they add an economic incentive for operators to hold a node, paid in crypto assets. This probably explains why a decentralized VPN like Deeper Network, created only in 2019, claims 65,000 nodes while the Tor network, after 16 years of service, deploys only 6,400[41].

37 "White paper - "The Nym Network The Next Generation of Privacy Infrastructure", Claudia Diaz, Harry Halpin, and Aggelos Kiayias, Nym Technologies SA Version 1.0, February 26, 2021, https://nymtech.net/
38 "Overview", Nym Network explorer, retrieved June 8, 2022, https://explorer.nymtech.net/overview
39 The Tor Project, history. https://www.torproject.org/about/history/
40 Download Tor Browser https://www.torproject.org/download/
41 Tor Metrics: https://metrics.torproject.org/

ISSUES AND QUESTIONS

Information and communication technologies are now essential infrastructures, just like roads, sewage systems, or electrical energy.

Large network infrastructures are still lacking in many developing countries, which means that in 2021, "*16% of the world's population will not have access to mobile broadband networks*[1] " according to the UN. The overall infrastructure constraints affect business productivity "*by about 40% for many African countries*[2] ".

As illustrated by Unicef's Giga project, the first challenge of electronic communications is access to the Internet, particularly in schools, to enable new generations to learn and appropriate new digital uses.

The network infrastructure enabling Internet access requires very heavy investments. Will we see blockchain initiatives that allow for innovation in the area of Internet access, particularly through the development of mesh networks?

Mobile data sharing on blockchain raises the issue of Internet access, especially in developing countries. It can be a solution as mentioned before, but this solution relies mainly on the initial access to a classic mobile network. How to ensure a good quality connection, continuously and to all?

Can blockchain-based Internet access services, therefore, avoid the need for greater infrastructure investments in these countries? On the contrary, can they reduce the number of infrastructures needed to ensure a good network connection for all, thus reducing the cost of these investments?

The development of virtual private networks (VPNs), used to connect to information sources or use services in a secure manner, reminds us of the need for tools that allow us to escape the censorship put in place by state-controlled Internet Service Providers (ISPs) and the surveillance of networks by unscrupulous companies. But how accessible are they?

1 Goal 9: Build resilient infrastructure, promote sustainable industrialization that benefits all, and foster innovation https://www.un.org/sustainabledevelopment/fr/infrastructure/
2 *Ibid*.

Aren't these services reserved for a trained elite with a certain technical background? Indeed, these decentralized VPNs are still complex to implement and use, notes Louis Bertucci, a researcher at the Louis Bachelier Institute[3].

"*To make them more accessible, an additional layer of abstraction will be needed to mask the use of these complex protocols. We could draw a parallel with the Internet itself. The Internet is a succession of complex communication protocols developed in the 1980s. However, the adoption by the general public came much later for two reasons: first, we had to build the infrastructure (servers, routers, etc.), and then wait for companies like Microsoft, Google, or Amazon (for AWS) to emerge and allow users to send an email with a simple click from their machine"* he continues.

Will the same thing happen with these still emerging technologies?

3 Interview with Louis Bertucci. June 30, 2022

EDUCATION & EMPLOYMENT

EDUCATION & EMPLOYMENT

Number of projects in the directory: 38

Number of active projects: 20

Name of active projects: African Blockchain Center for Developers ; AmwFund ; APPII ; BCDiploma ; BitDegree ; Blockcerts ; Code to inspire ; Credly ; DirectEd - Direct donation for education ; Diwala ; eMin ; Indorse ; Misthos ; Odem.io ; Open Badges ; Opolis ; Proof of Learn ; Prosoon ; Steam Role ; UNICEF Giga . *Can't find your project? You know of a project that is not listed in the directory? Send us an email* at bonjour@blockchainforgood.fr.

This chapter is also published online; if you wish to exchange, annotate, correct certain information, go to this document: https://blockchainforgood.fr/index.php/comment/?lang=en

Sustainable Development Goals 4 and 8 aim to ensure access for all to equitable, inclusive and quality education, lifelong learning opportunities, and full employment and decent work for all. We have identified about 30 blockchain initiatives that contribute to these goals, in the fields of education and diplomas, autonomous organizations in the labor market or transparency of working conditions for vulnerable populations.

Whether it is to certify a diploma, an education, an experience, or an employment contract, these blockchain initiatives necessarily rely on the identity of the person receiving these services and invoke the notions of decentralized identity and verifiable attestations, a subject about which we have devoted an entire chapter. (see chapter “Identity & Ownership”).

The contribution of blockchains in the field of digital identity is to devolve the current model based on authentication and access control of a person, managed by an organization, to a model based on the verifiability of attestations controlled by that person.

Education and Diplomas

The most widespread use case in the field of education is that of diploma certification, where the use of blockchains makes it possible to maintain the integrity of a register without it being centralized. It is both extremely difficult to falsify such a register and very simple for a company to check in this same register if a candidate is indeed a graduate of the school.

APPII in England, **Smart Certificate** in Belgium, **Diwala** in Norway, **Blockademia** in Croatia, **BCDiploma** or **Prosoon** in France are some of the companies and startups deploying such

a degree certification service. As early as 2016, pilot projects were conducted in Kenya and even in India, in 2018, where 5 million students graduate each year.[1]

Odem, a decentralized platform created in 2017 in Zug, Switzerland that connects employers, students, and trainers without intermediaries, explains: *"the way we learn, work, recruit, and train has changed dramatically in recent years, but the underlying infrastructure that supports this ecosystem has not"*.

Regularly denounced by schools and companies, diploma fraud is a scourge that is constantly worsening. So much so that companies such as Verifdiploma, founded in France in 2001, have launched themselves into this niche market of authenticating the diplomas and professional experience of candidates.

France has some 3,500 higher education institutions, including 500 public institutions (universities, engineering schools, business schools, art schools and architecture schools) and some 3,000 private schools and institutes.[2]

Each year, Verifdiploma receives a list of new graduates from 2,500 of them, which the company keeps in a centralized database, claiming to screen 115,000 CVs per year.[3]

The promise of blockchain initiatives in the field of degree verification is to provide both higher education institutions and applicants with a secure way to prove the veracity of their degrees to employers, without the need for a middleman. The interest in setting up such an infrastructure is twofold.

For learners, it allows them to keep a history of their lifelong learning, and to share it selectively with an employer, without having to request or pay an institution to obtain a new copy of a diploma. For institutions, it allows them to maintain a record of diplomas in a secure and inexpensive way, considerably reducing the risk of fraud, all the while relieving the administrations of the burden of reissuing lost diplomas.

Such initiatives have emerged all over the world, in Europe, the United States, India or even Africa. In Italy, **Almacert**, conceived by FlossLab[4] in 2018 and developed in collaboration with the

1 "Blockchains and Education", Allan Third, Kevin Quick, Chris Valentine, Michelle Bachler, John Domingue, Knowledge Media Institute of the Open University, Knowledge Media Institute of the Open University for the European Union Blockchain Observatory and Forum, December 5, 2019, https://www.eublockchainforum.eu/sites/default/files/research-paper/blockchain_observatory_education.pdf
2 "Higher Education in France", EuroGuidance, retrieved May 31, 2022, https://www.euroguidance-france.org/coming-venir-france/venir-en-france/lenseignement-superieur-france
3 "To find a job, they lie about their degree", Chloé Marriault, start.Les Echos, May 7, 2021, https://start.lesechos.fr/travailler-mieux/recrutements-entretiens/pour-trouver-un-emploi-ils-mentent-sur-leur-diplome-1313415
4 "Metafora", Flosslab, retrieved May 31, 2022, https://www.flosslab.com/

University of Cagliari, *"offers European universities the possibility to certify their graduates' diploma supplements through the Ethereum public blockchain".*

The **Digital Credential Consortium**, created in 2018 by twelve universities in the United States, Germany, Canada, Mexico, and Italy,[5] and hosted at the Massachusetts Institute of Technology, aims to deploy *"a trusted, distributed, and shared infrastructure that becomes the standard for issuing, storing, presenting, and verifying digital academic credentials"*.[6]

Announced in May 2021, in France, **the University of Lille** now issues its students a diploma as well as a digital credential.[7] 20,000 students graduating in 2020 have received *"a permanent link to an unforgeable and verifiable web document, translated into English, that he or she can present to an employer, an association or for further study, in France and abroad, allowing the authenticity of the diploma to be verified"*.[8]

In April 2021, the **Ethiopian government** signed an agreement to implement a decentralized digital identity solution for the 5 million students in the country's 3,500 schools[9] in order to allow them to benefit from the digital certification of their diplomas (see chapter "Identity & Ownership"). Obtaining a copy of one's diploma in countries with a mature education system does not pose a major problem. This is not the case in countries where the education system is weak.

The Ethiopian Ministry of Education currently has no data or visibility on educational outcomes until the last year of school, when students leave the education system. By maintaining a tamper-proof record on the **Cardano** public blockchain using the decentralized identity system **Atala Prism**, the country plans to solve the fact that *"it is virtually impossible for students to prove their academic achievements to potential employers or institutions of higher learning, which often severely limits their prospects".*[10]

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5 Delft University of Technology (The Netherlands) Georgia Tech (USA) Harvard University (USA) Hasso Plattner Institute, University of Potsdam (Germany) Massachusetts Institute of Technology (USA) McMaster University (Canada) Tecnologico De Monterrey (Mexico) TU Munich (Germany) UC Berkeley (USA) UC Irvine (USA) University of Milano-Bicocca (Italy) University of Toronto (Canada)
6 "Our Technology", Digital Credentials Consortium, retrieved May 31 2022, https://digitalcredentials.mit.edu/
7 "Digital credentials for all University of Lille graduates", University of Lille, Press Release, May 28, 2021, https://www.univ-lille.fr/fileadmin/user_upload/presse/presse_2021/CPDematteStoklien.pdf
8 "20,000 digital credentials of degree completion issued by the University of Lille", University of Lille, Press Release, February 10, 2022, https://newsroom.univ-lille.fr/fileadmin/user_upload/presse/2022/v20.000attestationsnumeriques.pdf
9 "Ethiopia's blockchain deal is a watershed moment for the technology, and for Africa", Iwa Salami, The Conversation, 20 https://theconversation.com/ethiopias-blockchain-deal-is-a-watershed-moment-for-the-technology-and-for-africa-160719
10 "Atala Prism", Project Management Institute, retrieved May 31, 2022, https://www.pmi.org/most-influential-projects-2021/50-most-influential-projects-2021/atala-prism

Diwala, established by Norway and Uganda in 2018, is a platform that enables *"secure and efficient issuance and verification of certificates or credentials and strives to serve the population of 1.8 billion people worldwide who live without a digital identity and are unable to prove their education, work and financial history".*

Diwala, started from the realization that certificate fraud is a major problem for the education system in Uganda, explains that *"when a student graduates from a Ugandan university, they receive a paper copy (the official document with the seal) and an electronic copy of their diploma (a paper that takes the place of the actual document). In order to validate their degree, students must then obtain various stamps and signatures from various sources. Unfortunately, these processes can be time-consuming: students have reported that it takes up to six months to receive their certificate after graduation. The validation processes required to verify certificates can cost up to two or three hundred dollars, depending on how many certificates you have".*

The platform builds on **uPort**, which has been split since 2021 into two projects, **Serto**, a "low code"[11] decentralized identity software solution, and **Veramo**, a JavaScript framework that allows anyone *"to easily use cryptographically verifiable data in their applications, and implement DIDs, verifiable credentials, and data-centric protocols to deliver next-generation functionality to their users"*.[12]

Since 2016, **two methods of guaranteeing the authenticity of a diploma have been experimented with.** One is to time-stamp and register a diploma in a blockchain, such as the initiatives led by the Holberton engineering school in San Francisco, in the United States, with the company **Bitproof**;[13] by the École Supérieure d'Ingénieurs Léonard-de-Vinci (ESILV) in 2016; by the École Nationale Supérieure Mines-Télécom Atlantique Bretagne (IMT Atlantique) in 2017, in partnership with the startup **Woleet**, which specializes in anchoring documents in blockchain; and by Digiposte, the digital strongbox solution of the La Poste group. *"Each graduate receives, in addition to his or her paper diploma, a digital version of it accompanied by a certificate of anchoring in the bitcoin blockchain"*,[14]

11 No code / low code: "New trend in the IT sector linked to the appearance of 'No code development platforms' (NCDPs). These structures offer the possibility to people without any technical skills to create all kinds of web applications through graphical interfaces and configuration panels, without going through traditional computer programming", Jacques-André Fines-Schlumberger, The European Journal of Media and Digital, N°54bis-55 Autumn 2020 https://la-rem.eu/2020/12/no-code/
12 "Introduction", Veramo, retrieved May 31, 2022, https://veramo.io/docs/basics/introduction
13 "Blockchains and the law", Boris Barraud, Revue Lamy Droit de l'immatériel, Lamy (print) / Wolters Kluwer electronic edition 2018, pp.48-62. ffhal-01729646e
14 "Your degree in the blockchain, what advantages?", Marianne Laurent, Monde des Grandes Ecoles et Universités, May 16, 2017, https://www.mondedesgrandesecoles.fr/diplome-blockchain-avantages/

explains Marianne Laurent, then in charge of innovation and creativity at ITM Atlantique.

The other method is to rely on a decentralized identity system / verifiable credentials (see chapter "Identity & Ownership"), like **Prosoon** which allows the issuance of verifiable credentials on several EVM* compatible infrastructures, like Ethereum, Tezos, Polygon or Solana. According to the **Digital Credential Consortium**, *"a verifiable credential can be imagined as the combination of two elements: a document and an envelope in which that document is placed. The document is like the piece of paper a university issues to a graduate, which contains the recipient's name and a description of the credential he or she received. The envelope protects the contents of the document so that it cannot be altered and reliably communicates the authenticity of its contents"*.[15]

Relying on an ecosystem of decentralized identity and verifiable educational credentials seems to be a boon for all the actors interacting with each other: learners, whether it is their first degree or a later training, training institutions and employers, and any third party likely to verify the authenticity of a degree.

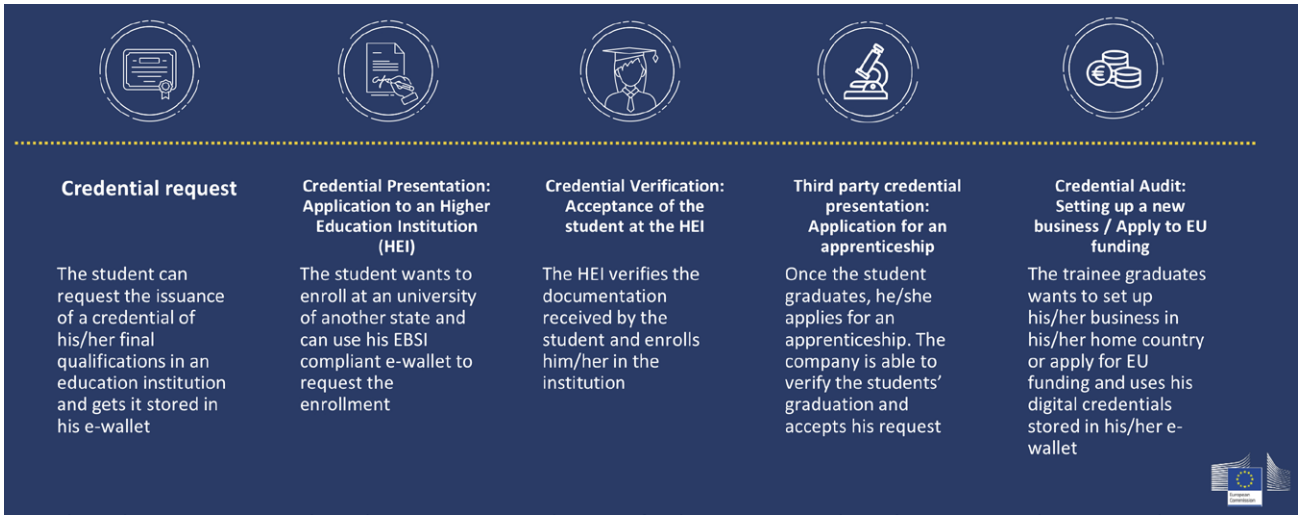
For the learner, it is a matter of having verifiable certificates corresponding to all of their diplomas and lifelong learning, even if the institution closes, and to be able to share them, selectively or otherwise, with a third party (employer, public services, professional organizations, etc.) with the assurance that this information will not be exploited without their knowledge.

For the training institution, the primary interest is to be able to rely on standards that guarantee the integrity and confidentiality of learners' information while being much less expensive to implement than a centralized or outsourced system. It also saves time for the administrative teams in charge of sending copies of diplomas lost by learners.

Finally, for the employer, it is the guarantee of receiving resumes with certified diplomas without the need for a third party to verify their authenticity and at a cost close to zero.

On the recruitment market, it also permits favoring the use of anonymous CVs, which consists in respecting equal opportunity and fighting against discrimination in hiring through a recruitment process based only on the skills and diplomas of a candidate, without requiring access to their identity or name until they are asked for an interview.[16]

15 White paper: "Building the digital credential infrastructure for the future" https://digitalcredentials.mit.edu
16 "Discrimination in hiring: a phenomenon that remains widespread and persistent", Louise Couvelaire, November 24, 2021, https://www.lemonde.fr/societe/article/2021/11/24/discriminations-a-l-embauche-un-phenomene-qui-reste-generalise-et-persistant_6103458_3224.html



EBSI *Use case: Diplomas management. Overview of core functionalities.*
Source : " European Blockchain Service Infrastructure ", Daniel Du Seuil – ESSIF convenor and Belgian representative in EBP, OECD, Interreg, https://northsearegion.eu/media/16680/ebsi-explained-by-daniel-du-seuil.pdf

Given the diversity of initiatives, the interest in relying on a system of verifiable attestations should make it possible to ensure the interoperability of different services by using common standards.

This is the purpose of the European Blockchain Services Infrastructure (EBSI),[17] which we discuss in the "Government and Democracy" chapter. EBSI is a joint initiative of the European Commission and the European Blockchain Partnership, whose purpose is to leverage the standardization of blockchains to *"accelerate the creation of cross-border services for public administrations and their ecosystems in order to verify information and make services more reliable"*.[18]

Since 2020, EBSI has been deploying a network of distributed nodes across Europe, supporting applications focused on several use cases including diploma certification.[19]

This is part of its effort, initiated with the Council of Europe and UNESCO/ CEPES in 1996, to improve international transparency and facilitate the academic and professional recognition of qualifications such as diplomas, academic achievements, certificates and training in general.

Moreover, a diploma is often only the reflection of a general education without being able to show the granularity of the components of a training, such as modules, courses, internships,

17 "Introducing EBSI", European Commission, retrieved May 31, 2022, https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/
18 *Ibid.*
19 "Diploma Functional Scope Skip to end of metadata", Marta Pastor, Regina dela Eva, European Commission, May 26, 2021, https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/Diploma+Functional+Scope

dissertations, practical cases, etc. On the European model of ECTS (European Credit Transfer System), set up in 1989 within the framework of the Erasmus program to facilitate the academic recognition of periods of study abroad and to develop the quality of student mobility in Europe, one could imagine not only the certification of diplomas but of "course units".

The certification of diplomas and apprenticeships is probably only a first step towards the more global certification of professional paths and experiences throughout the life of individuals, who are increasingly mobile, in line with a rapidly changing labor market.

Job Market

It is conceivable to translate the certification of diplomas to the certification of professional experience. The issuer of a verifiable certificate would no longer be an educational institution but a company, certifying that a person has indeed worked within it.

For example, **Talent Cloud**,[20] led by Valerie Thomas, Head of Talent Mobility Strategy for the Treasury Board of Canada Secretariat, is an initiative that is developing new models for recruiting and engaging talent in the Canadian public service sector.

The idea of Talent Cloud is to offer employees and employers more information than just a degree, such as *"competency-based descriptions that can be more precisely matched up with skills/competencies"*[21] explains Kim Hamilton Duffy of the Digital Credentials Consortium (see above). Hugo Spiess, founder of Prosoon, explains that *"micro-credentials allow learners' skills and experiences to be valued beyond diplomas, allowing recruiters a more accurate analysis of candidates' qualifications and interests"*.[22]

20 "Talent Cloud Results Report", Government of Canada, retrieved May 31, 2022, https://talent.canada.ca/en/2000/01/01/504-blockchain.html
21 "Blockchain Can Disrupt Higher Education Today, Global Labor Market Tomorrow", Andrew Singer, The CoinTelegraph, June 14, 2020, https://cointelegraph.com/news/blockchain-can-disrupt-higher-education-today-global-labor-market-tomorrow
22 Interview with Hugo Spiess, founder of Prosoon, June 30, 2022.

Some companies are looking at how blockchains and cryptocurrencies could impact payroll management within companies, particularly to automate and secure cross-border wage payments.

ADP Inc, a U.S.-based provider of business outsourcing solutions related to human capital management (payroll, time and attendance, human resources), employing some 60,000 employees worldwide, has been exploring the potential of crypto currencies in the field since 2018 and even filed a patent in 2019 on a "Payroll Based Blockchain Identity"[23] that relies on the **Ripple** blockchain, a public permissioned blockchain managed by banking and financial intermediaries.[24]

The World Food Program's (WFP) **Empact** innovation project connects unbanked students at risk of hunger to the global digital economy through a micro-work platform and crypto-currency wallet. Based on the realization that the data annotation industry in the field of artificial intelligence (AI) is booming, the World Food Program built the Empact digital training program with Corsali and **Celo** for informal sector workers in developing countries, with a special focus on those who do not have access to financial institutions and do not have bank accounts to receive payments.

The project began in 2016 and, six years later, 13,500 refugee and disadvantaged youth, 54% of whom are women, in Colombia, Iraq, Kenya, Lebanon, Palestine, Turkey and Zimbabwe have benefited. Ian Kimaru, 27, a resident of Kenya's largest slum in Kibera, said: *"in just three months, I became familiar with new IT tools and learned coding and web development through a custom course on the Pluralsight learning platform.*[25] *These new skills opened up huge opportunities for me in the global digital job market, as I could propose freelance IT jobs on the internet"*.[26]

Corsali is a machine learning platform powered by freelancers tagging data for pay from their cell phones.[27] The micro-work platform integrates a crypto-currency wallet, allowing participants to be paid instantly in Celo dollars (cUSD), a stable crypto-currency indexed to the U.S. dollar, which they can further convert to local currency with the popular MPESA app depending on the country they are in.

23 "Payroll based blockchain identity", United States Patent Application, FPO, November 8, 2018, https://www.freepatentsonline.com/y2018/0322587.html
24 Ripple allows financial institutions that are part of the RippleNet network to send and receive money around the world instantly and for low transaction fees. Ripple: https://ripple.com/faq/
25 "Our latest picture", PluralSight, retrieved May 31, 2022, https://www.pluralsight.com/
26 "Tech Training Tackles Youth Unemployment in Kenya's Largest Urban Slum - Five Personal Stories from Kibera", WFP Innovation Accelerator, Oct 30 2020, https://wfpinnovation.medium.com/tech-training-tackles-youth-unemployment-in-kenyas-largest-urban-slum-five-personal-stories-6b636e0b741c
27 "Corsali - Founders Series"," Amy Slawson, Medium, June 22, 2021, https://medium.com/virtuous-ventures/corsali-founders-series-991dd20436ee

This type of initiative led by the World Food Program could not go through a bank or financial intermediary as their fees are prohibitive for micropayments.

For others, the future of the labor market lies in Decentralized Autonomous Organizations* (DAOs). For some, this would mean moving from a full-time employment contract for a single employer to performing periodic contributions for several autonomous organizations, with the management, contracts, assignments, payments and even contributions being handled automatically by this new type of structure.

For Steve Glaveski author of "Time Rich: Do Your Best Work, Live Your Best Life", *"instead of working from a central office year-round and having two to four weeks off, most DAO contributors will likely work remotely, connect in virtual social spaces such as **CryptoVoxels** or **The Sandbox**, and for several days or weeks a year meet in real life for inspirational conferences and retreats"*.[28] This vision of tomorrow's labor market does not necessarily imply an impoverishment of independent workers, notably those of the gig economy.

An initiative led by **Gitcoin** gives a glimpse of how a working community, in this case computer science, can interact through a Decentralized Autonomous Organization (DAO*). Gitcoin presents itself as *"a platform where you get paid to work on open source software"* including programming, development, web and design.

More precisely, GitcoinDAO brings together a two-sided marketplace with, on one hand, computer developers and, on the other, people or companies that finance the development of open source software. GitcoinDAO describes itself as *"a community of Internet citizens who build and fund digital public goods, such as open source software"*.[29]

Launched from Boulder in the United States in 2017, Gitcoin has raised $62 million to fund the work of more than 310,000 software developers worldwide across 2,400 projects. For its users, the implementation of a DAO allows them to avoid bureaucracy, dispense with trusted third parties, and avoid the costs associated with international payments and credit cards, by relying on the Gitcoin token.

28 "How DAOs Could Change the Way We Work", Steve Glaveski, Harvard Business Review, April 7, 2022, https://hbr.org/2022/04/how-daos-could-change-the-way-we-work
29 "TLDR - What is Gitcoin? [Updated May 2022]", Gitcoin, retrieved May 31, 2022, https://gov.gitcoin.co/t/tldr-what-is-gitcoin-updated-may-2022/8694

Gitcoin[30] is built on the permissionless Ethereum public blockchain and serves two functions.

The first function of Gitcoin is to fund open-source software, raising money in crypto-currencies through a quadratic crowdfunding system.

Quadratic Funding

Quadratic funding is a funding system based on the fundamental principles of quadratic voting.

What is quadratic voting?

Quadratic voting is a voting system in which citizens express their degree of preference from a starting balance of voting credits. Each citizen allocates their credits to the candidates they want. The credits represent the "price" that a voter is prepared to pay to give a vote to a candidate.

However, the price of a vote is not fixed: **each additional vote** given to a candidate **costs** the voter **more credits.** The price in credits corresponds to the square of the number of votes it represents: 1 vote = 1 credit, 2 votes = 4 credits, 3 votes = 9 credits, 4 votes = 16 credits, 5 votes = 25 credits, ... We can say that the price in credits evolves quadratically.

What about financing?

Quadratic financing is inspired by the eponymous voting system to combat the concentration of power in project financing by a few large investors. The quadratic financing system has two phases:

30 "Gitcoin Core", Github, retrieved May 31, 2022, https://github.com/gitcoinco

The first phase corresponds to a spontaneous allocation of investors' money to projects that interest them. Some projects get more or less money, from more or less investors.

However, quadratic financing involves a second phase in which a different type of fund allocation mechanism is used.

The key principle is that **the number of contributors**, not the initial amount raised, **determines which projects receive more**. In other words, a project that has received donations from a large number of contributors will receive a larger amount of money than it originally raised.

Conversely, a project that has received a lot of money from a small number of contributors will ultimately see its funding decrease.

Let's take the example of two projects that each initially receive 100 GTC, the Gitcoin crypto-currency. Project 1 receives 100 GTC from **a single donor**, project 2 also receives 100 GTC but from **ten donors**. Based on quadratic funding, Project 2 will eventually receive **190 GTC**, whereas Project 1 will receive only **10 GTC**.

The second function of Gitcoin is to connect developers with open-source project owners, the meeting of supply and demand being organized around remuneration in crypto-currency for the developer. Through these two functions, Gitcoin foreshadows facets of tomorrow's economy: on one hand, a more horizontal financing of the economy, avoiding any form of concentration of capital invested in a small number of projects thanks to the quadratic system; and on the other hand, a peer-to-peer labor market, where supply and demand for labor are directly connected.

Workers' Rights

Decentralized Autonomous Organizations

Misthos or **Opolis** are part of a movement in the crypto-currency world to create employment models that are less centralized than a traditional company, through Decentralized Autonomous Organizations* or even multi-signature wallets*.

Founded in 2017 in Denver, USA, **Opolis** began as a Digital Employment Cooperative (DEC) for self-employed individuals to fund health benefits, receive shared services, and use a payment system inherent to the autonomous organization, among other things.

In 2019, Opolis received a development grant from the **MakerDAO** Foundation[31] to integrate MakerDAO's Dai crypto-currency, a stablecoin* asset, with the Opolis DAO. In the United States, users of the online cooperative can use Dai to fund their membership, contribute to health insurance, contribute to retirement plans and automate tax compliance.

They can choose to be paid in Dai or fiat currency. Opolis, in 2021, has become a *"blockchain-based response to the rise of the gig economy"*,[32] i.e. a response to labor paid by task and managed via mobile applications offered by digital platforms (Uber, Deliveroo etc.), and a professional employment organization (PEO) with the objective of, among other things, facilitating cross-border payments with the stable crypto-asset Dai.

Misthos founder Justin Carter explains the model as *"moving away from an employee-employer relationship to a group consensus on value delivery"*.[33]

Misthos, launched in Berlin, Germany in 2017 is *"a decentralized collaborative finance management application"*. It is a multi-signature wallet developed on the decentralized application platform* Blockstack.[34]

This wallet is designed so that all participants in a project (team, financiers, other organizations) can manage the distribution of income, received in the form of bitcoins, among their individual members.

It is certain that these services are currently primarily aimed at a specialized audience, most of whom work in the crypto-currency ecosystem. Opolis has close ties with ConsenSys, the Ethereum design studio,[35] but these experiments in self-organization may foreshadow future transformations of certain organizations whose goal is to collaborate better, especially in a remote work environment.

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31 "Decentralized Employment Ecosystem Opolis to Integrate MakerDAO's Dai Cryptocurrency", Danny Nelson, CoinDesk, September 18, 2019, https://www.coindesk.com/markets/2019/09/18/decentralized-employment-ecosystem-opolis-to-integrate-makerdaos-dai-cryptocurrency/

32 "Better work in the gig economy", Jacques-André Fines Schlumberger, The European Media Review, N°53 Winter 2019-2020, https://la-rem.eu/2020/03/better-work-in-the-gig-economy/

33 'Blockstack's First Business App Wants to Help Employees Earn More Crypto', Leigh Cuen, CoinDesk, July 30, 2018, https://www.coindesk.com/markets/2018/07/30/blockstacks-first-business-app-wants-to-help-employees-earn-more-crypto/

34 Blockstack is a *"decentralized application development platform running on the Bitcoin blockchain. It provides a solution for decentralized authentication, authorization and storage of data secured by the Bitcoin blockchain. With Blockstack, users control their data and applications run on their devices. There are no middlemen, no passwords, no massive data silos to breach and no services that track users across the Internet".* "Frequently Asked Questions", Misthos, retrieved May 31, 2022, https://www.misthos.io/faq

35 ""Blockstack's First Business App Wants to Help Employees Earn More Crypto", Leigh Cuen, CoinDesk, July 30 2018, https://www.coindesk.com/markets/2018/07/30/blockstacks-first-business-app-wants-to-help-employees-earn-more-crypto/

Workers' Rights

In 2020, **VerifiK8**, a sustainability company working with agribusinesses in Southeast Asia, and **Diginex Solutions**, a technology company specializing in responsible supply chains, piloted **eMin**. eMin, developed by Diginex, is a **Tezos** blockchain-based system that aims to enable the private sector to identify forced labor on their supply chains, particularly with regard to the working conditions of agricultural workers in Thailand, a sector that employs more than 11 million workers and a significant number of migrant workers from Myanmar, Laos and Cambodia.

The pilot reached out to two specific groups of farmworkers in October and December 2020 to *"better understand their risk of exposure to modern slavery, their interest in securely storing their contracts and other key work documents, and their comfort level with the technology"*:[36] permanent workers with formal employment contracts, and seasonal workers employed through verbal agreements.

While the former showed little interest in the tool, the latter were more responsive to eMin. This second group, consisting of 58 sugarcane, rice and rubber workers in Nong Bua, Sikhoraphum and Surin districts, are villagers who own small rice farms in Nong Bua and become seasonal agricultural workers in Ratchaburi province during the sugarcane harvest. These seasonal agricultural workers typically spend two to three months working on a farm and receive an advance on their wages, which makes it complicated *"to understand the link between hours worked and payment received, especially if employers make other deductions for interest or other 'costs' (such as food, tools, and transportation)"*.

In addition, this wage advance system binds workers who can no longer leave their jobs even if they are abused. Thus, some workers suggested that eMin could be used to clearly document their loan and employment terms, including payments and in-kind costs (such as food and transportation). *"Documenting these critical elements at the beginning of the employment relationship on an immutable ledger would provide more transparency and trust for both parties and reduce the risk of exploitation"* explains Leanne Melnyk of Diginex and Juliette Alemany of Verifik8.[37]

Although the project is still being tested, it is a crucial issue in supply chain traceability. As we have seen in the chapter "Supply Chain & Logistics", the transparency of a supply chain is only worthwhile if it starts with the first link in the chain.

36 "Using Frontier Technology to Detect Hidden Labour Abuses in Agricultural Sectors in Thailand", Leanne Melnyk, Juliette Alemany, Delta 8.7, February 26, 2021, https://delta87.org/2021/02/using-frontier-technology-detect-hidden-labour-abuses-agricultural-sectors-thailand/?lang=fr
37 *Ibid.*.

This initiative joins that of **Koa** in the field of cocoa bean and pulp harvesting, based in Switzerland and Ghana, which, in March 2022, claims to have paid 2,250 small Ghanaian farmers 263,000 euros and also to have avoided 390 tons of food waste.[38] Koa[39] trains cocoa farmers to, in addition to harvesting cocoa beans, process the previously discarded pulp, allowing them to earn additional income and be paid promptly after the production process (see "Supply Chain & Logistics" chapter).

Finally, the **Workers Well-Being Program** initiative[40] led by the jeans brand Levi Strauss, together with ConsenSys, Harvard University Public Health Graduate School and the think tank New America, targets the use of a blockchain to collect the results of surveys from employees of three of their Mexican companies regarding their working conditions. The blockchain implementation allows employees to respond anonymously to surveys, allowing critical information about the level of company management to be fed back without self-censorship.

The results are stored in a private blockchain, which can nonetheless be consulted by any member of the company. The Mexican authorities are also able to consult the results, being a member of the network.

This type of scheme aims to go beyond the labor legislation in Mexico by creating a direct link and relying on information provided directly by workers. This pioneering project, started in 2018, made its first impact report during 2020, based on a qualitative evaluation of the scheme that involved *"about 195,000 workers in 118 factories in 16 countries, representing 65% of the company's product volume"*.[41]

At Levi-Strauss, the participants acknowledged that they had received much richer and more documented feedback than usual, even if we do not yet have the necessary hindsight to assess the social impact of this initiative.

38 "Can Blockchain Fix the Chocolate Industry's Labor Issues?", Jill Ettinger, Green Queen, March 24, 2022, https://www.greenqueen.com.hk/blockchain-cocoa-labor-issues/
39 "Koa taking transparency to the next level with Seedtrace", Seedtrace, May 31, 2022, https://seedtrace-website.cdn.prismic.io/seedtrace-website/5270d7b5-7a21-408e-8661-beed0de6dd7e_Seedtrace_CaseStudy_KOA_01-zusammengefügt%2B%281%29.pdf
40 "Blockchain for Factory Workers: A Study of Levi's Worker WellBeing Program", Mary Basile, Golden Gate University School of Law GGU Law Digital Commons 3-25-2020. https://digitalcommons.law.ggu.edu/cgi/viewcontent.cgi?article=1000&context=blockchain_law
41 Worker Well-being https://www.levistrauss.com/how-we-do-business/worker-well-being/

ISSUES AND QUESTIONS

How can interoperability of certificates related to diplomas be ensured? It turns out that between the two methods used by startups and companies to guarantee the authenticity of a diploma or certificate - time-stamping the document in a public blockchain or relying on decentralized identity and verifiable attestations - the latter seems to offer a framework more conducive to interoperability, for learners, training institutions, employers and any third party likely to verify the authenticity of a diploma. Europe seems to be moving in this direction, notably through the work of EBSI, which is deploying a network of distributed nodes to enable the certification of diplomas.[1]

Since the labor market is characterized by an employer/employee relationship, how do new forms of decentralized organization reinvent labor relations or communities working toward a common goal? While the Gitcoin initiative seems promising, it should be noted that the market in which it operates is imbalanced in favor of the supply side, i.e. computer developers. Their skills are extremely rare, especially for open-source projects. Thus, software developers are in a dominant position, which makes their hiring conditions attractive. What would be the consequences of adopting such a decentralization in a less imbalanced labor market?

As for blockchain projects aimed at improving working conditions, whether through contract registration or anonymous surveys, what good are they if built on private blockchains? Could these types of projects be developed on public blockchains?

If so, why would competing companies agree to share this type of information? Would they see it as interference in their private affairs, or as transparency in the working conditions of the “first links” of value chains that are still largely opaque, especially with regard to the working conditions of employees in countries of the southern hemisphere? What would be the adoptive factors or hindrances for this type of project?

1 “Diploma Functional Scope Skip to end of metadata”, Marta Pastor, Regina dela Eva, European Commission, May 26, 2021, https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/Diploma+Functional+Scope

LIST OF COMPANIES & PROJECTS

Build on public blockchains

0x
AAVE
Accredible
Acre Afric
Adhara
aenco
African Bl
Agrello
Agroplug
Aidcoin
Air-fox
Akash
Akoin
Akropolis
Algorand
Ambrosus
Aragon
Arbol
Arianee
Arweave
BenBen
BICOWG
Binded
Bit Sika
BitClout
Bitcoin Be
BitDegree
Bitfury Pr
Bitland
BitMark
Bitminutes
Bitnation
Bitpesa
Blockademi
BlockID
Blockstack
Bloom
Bottlepay
Brave (Bas
brightID
Brokoli Ne
BTU Protoc
Cajutel
Callisto
CarbonABLE
Carbonyzed
Cardano
CELO
Centrifuge
Changebloc
Chia
Circles
Circularis
Civic
Civic Ledg
Climate Fu
Climatetra
CO2DAO
Code to in
Colony
Compound
Credly
Curve
Cut.eco
CyberFM Ma
DAO IPCI
DAOhaus
DAOstack
DAppNode
Decent
Deeper Net
Democracy
Dent Wirel
Dether
Devery
DFinity
Diatom
Digiland
Digitary
DirectEd
District0x
Diwala
DOVU
DTube
eAgronom
Earthbanc
Eco Coin
ecoriseDAO
Eden DAO
efforce
Electis
Empowa
Encrypgen
Energy Web
Engie Power
Engiven
EthaVerse
Etherisc
Ethic Hub
Evergreen
Experty.io
Factom
Faircoin
Fiducia
Filecoin
FilmChain
FintruX
FlexFinTx
FlexiDAO
Flow Carbo
Freecoin
Galoy
GenoBank
Gitcoin
GivEth
GiveTrack

Golem
Gooddollar
Grassroots
Gravity
Green Worl
Greeneum
Grid Singularity
Grid+
Gridcoin
HashingDNA
Helium
HIT Founda
Holo
HOPR
Horizen
Humaniq
Humanscape
HydroCoin
ImpactMark
Indorse
Inflow Mus
IOHK
Ixo foundation
Jolocom
KamPay
Keeex
KelVPN
Kilt
Kin
Kivéclair
Klapcoin
Kleros
klimaDAO
Leman
Local Bitc
Logion
Longenesis
Lynx
Maidsafe
MakerDAO
Mediachain
MediBloc
MedicalCha
Minds
Minespider
Misthos
Moeda
Molecule
Muun
Mybit
Mysterium
Nebula Gen
Nexo
NFTb
Nori
NYM
Oceanus Fo
Odem
Opus
Orchid Lab
Originalmy
OriginStam
OriginTrai
OS City
Ozalentour
Pacifical
Pancake Sw
Parity.Tec
Patientory
Paxful
Pinkcoin
Polkadot
Promise
Propy
PubliQ
Pylon Netw
Qitmeer
RAZ Financ
REDD-Chain
Regen.netw
Remitano
Restart En
Retreeb
RightMesh
Royal
Rupee Bloc
Safe Haven
SALT
Sapien
Seeds
Share & Ch
ShareToken
Shivom
Sia
Sicpa
SkyChain G
Skynet
Smart Cert
Smart Valo
SmartCredi
SolarCoin
Solarfullc
Sovrin
SparkPoint
SpruceID
Stacks / H
Steem
Stellar
Storj
SUKU
SunContract
SureRemit
Syntropy
Tael
Taro (prot
Tecra
TE-FOOD
Telcoin
Tellor
The Egypti

The Giving Block
The Safe Network
The Sun Exchange
Threefold
Token Engi
Torum
Toucan Protocol
TrafiGuard
Treejer
Trustlines
UCASH
Uniris
Uniswap
URights
UTU
VeChain fo
Veramo
Verity Tra
Vezt
Vinchain
VitaDAO
Weifund
WePower
World Mobi
Xend
Zwei Space

Build on a blockchain other than public

1PLANET Marketplace
3air
Abra
ADMCS
Agri10x
Agrichain
Agridigital
Agriledger
Agri-wallet
Agrotoken
Agrotrust
AgUnity
Aid:Tech
Akasha World
Alice.si
Allinfra
Althea
Amchart
Ampere Energy
AmwFund
AntLove
APPII
Arcade City
Arcadia Blockchain Technologies
Archipels
Arc-net
Arup water exchange
Astri
Atato
Avano
Avyantra
Aware
AXIchain
B Protocol
Bananacoin
BanQu
Bart.Digital
Bazaar Tech
BCDiploma
BeefLedger
BetterChain
Betterpath
Bext360
BFIo
Bisq
Bitcliq - Lota Digital
Bitcow
Bitlumens
Bitrefill
Bitt
Bittunes
Blockcerts
Blockchain Charity Foundation
Blockchain Helix
Blockchain My Art
BlockchainyourIP
Blockfreight
BlockMedx
Blok-Z
Bloombloc
Botkeji (by Kaoun)
Bowhead Health
Brac blockchain pilotes
Breaker
Bridgit
Bron.tech
Brooklyn Microgrid
BurstIQ
Cambiatus
Carbonfuture GmbH
CarbonX
CareChain
CargoChain
Cellulant
CentBee

Cerealia
Chainvine
Chainvine
Change Healthcare
Choco4Peace
Chooose
Chromaway
Chronicled
Chynge
Circularise
CircularTree
Circulor
Cirplus
Citizen Health - Citizen DAO
Civic Ledger
Clara Diamond Solutions
Clear Trace
ClickPesa
ClimateDAO
CO2ken
CobaltBlockchain
Coinify
Coins.ph
Colendi
Commonshood
Compellio Registry
Connecting Food
ConsilX
Coorest
Covantis
CoverUS
Crayonic
Crowdforce
Crypto Development Fund (CDF)
Datafund
dclimate
dClinic
Decapolis
Decent (healthcare)
Deloitte's Smart Identity
DEMARS
dGE - Diggi
Dharma
Dibiz
Diem (ex Libra)
Digital Bazaar
Digital Citizen Fund
DistributedTown
DNAtix
Doc.ai
Doingud
Domi
Dorium
EBSI
EcoChain
EcoKraft
EduCTX
Ehab
Ejara
Electrify.Asia
Electron
Embleema
eMin
Empower
Emurgo
Energy Unlocked
EnergyChain
Enervalis
eSolidar
evan.network
Evercity
Everex
Everledger
Evertrace
Everty
Evolution Energie
EVSHARE
Exalti
Excess Materials Exchange
eyeWitness to Atrocities
FairChain Foundation
Fairfood
FAO charcoal in Ivory Coast
FAO farming in Papua New Guina
Farm
FarmaTrust
Farmer Connect
Fishcoin
Flutterwave
Followmyvote
Food Trax
Foodchain
FoodGates
Foodlogiq
Foodtrack
Forest Stewardship Council (FSC)
Fransine Farm Norway
FutureThinkers NFT
Gab
Gaiachain
Gainforest
Gainfy
Gavea
GemFair
project
Genecoin
Geneyx
Genuine Way
Geon Network
Givecrypto
Gmerits
Golandregistry (UN in Afghanistan)
GrainChain

Grapevine
Guardtime & Estonia
eHealth strategy
Hala Systems
Hara
Hashed Health
Health Verity
Health Wizz
Healthcoin.nl
HIE of One
Hive online
Homeward
Horizon State
IBISA
IBM Food Trust™
IcrowdU
ID2020 Alliance
Iden3
Impact Cred
Inclusivity.network
Insurwave
International Platform for Insetting (IPI)
intiva
Inuk
Invictus Capital
Involve Mint
IOMOB
Irene Energy
Irisguard
Iryo
iSolve
Kidner
KimboCare
Kiwi New Energy
Korapay
KYC-Chain
KYG Trade Foundation
Kyve
Land LayBy
Leap
LegitDoc
Little Phil
LO3 Energy
Lucidity
Lumoin
lunaDNA
Lympo.io
M-Akiba
MAP
Mattereum
Medici Land
MediLedger
Meditect
Medrec
Medvice
MedX Protocol
Mimosi (PeerLedger)
Minexx
Mintrax
Mixing Bowl
M-Kopa Solar
Mobilized construction
Modum
Mojaloop
MonedaPAR.com
Monegraph
Monerium
Money Track
Moonjelly DAO
Morpheus
MyHealthMyData
Nano Health
Neco
Netservice
NutraSign
Nyala
OLI Systems
OmegaGrid
Omnichain
Open Badges
Open Earth Foundation
Open Forest Protocol
Open Health Network
Open Packaging Network
OPN
Open Time Stamps
OpenCerts
OpenSC (WWF) & Nestlé
OpenSurface
Opolis
Oradian's Stellar
OURZ
Ownest
PayCase
Peer Ledger
Peertracks
Pesabase
PharmaTrace
Plastic Bank
PlastiCoin
PlataformaVerde
PledgeCamp
PointNurse
Polys
Popcorn network
Porini.Foundation
Poseidon Foundation
Possible Today Foundation
PowerLedger
Powerpeers
PPPHealth4All
Prescrypto
Procivis
Project Greshm
Proof of Impact
Proof of Learn
Prosoon
Prosume

Provenance
Proyecto Colmena
QLAY
Quanti Health
Raay
Raise
RCS Global and the Better Sourcing Program
Re | Source
Realchain
Reason
RECDefi
Red Grid
REMIIT
Reneum (Sindicatum Blockchain Technologies)
Resonate
Retraced
Rewatt
Ribbon blockchain
Rice Exchange
Ricult
Ripe
Rohingya Project
S3FOOD
Sandblock
ScanTrust
SecureKey and IBM
Senditto
Serto
SESO
Sharehope
ShoCard
Singapore Smart Nation Initiative
Skuchain
Smart Dubai
SmartAgro
Social Alpha Foundation
Solar Bankers
Solid World DAO
SolShare
SourceCred
Spectral
Spherity
Spiritus
Spring Labs
SPROUT
Statwig
Steam Role
Substratum
Sunchain
Superfluid
Suretly
Sustainable Bitcoin Standard
TagONE
Talao
Tempo's Stellar integration
TEO : The Energy Origin
TerraBioDAO
TextileGenesis
Thailand digital identity
The Bounties Network
The Commons Stack
The new fork
The Other Bar
TiiQu
Tokit (Breaker)
Topl
Trace My Egg
Tracr
TradeLens
Transcrypts
Transparency One
Transparent Path
TraSeable Solutions
TREECYCLE
TruBudget
Truepic
TurboCereal
Twiga Foods
Tykn
Ubitquity
Unbiased
UnBlocked Cash Oxfam
UNICEF Giga
UPCO2
Uphold
Urban Array
Uulala
Venezvit
VERFiD Pet
Veridium Labs
VerifiK8
Verif-y
VeriTag
veritise
Verstegen and Fairfood Nutmeg
Vevue
Vidchain
VipiCash
Voatz
Volt Markets
Vumi's Stellar Integration (Praekelt Foundation)
Waba
Wave
WFP Building Blocks
Wholechain
WIN
Woleet
Women's coin
Wood Tracking Protocol
Wordproof
Worldremit
WPPEnergy
Wren

Wyre
Xago
Yave Blockchain Platform
Yensesa
Youbase / Cortex
Zenome
Zero Carbon Project
ZeroNet
Zlto

GLOSSARY

Altcoin : An altcoin refers to all alternative crypto-assets to bitcoin. Since the creation of the first bitcoin in 2009, coinmarketcap.com counted 2,360 as of July 22, 2019, 10,429 as of June 15, 2021 and 20,246 as of July 2022.

AMM : *Automated Market Maker.* A protocol for automatically calculating the exchange rate between two crypto-assets. The automated market maker is the basis of all DEX (Decentralized Exchange), and allows its users to exchange crypto-assets with each other in peer-to-peer, without going through a third party. The first platform to use this principle is called Uniswap.

API : In computer science, an Application Programming Interface is a standardized set of classes, methods, or functions that serves as the front end through which a blockchain will offer services to other software. A blockchain API specifies how computer programs will be able to make use of the functionality and distributed data accessible in a blockchain's ledger.

Atomic Swap : In finance, a swap is a financial exchange contract. In the field of crypto-assets, an Atomic Swap is a peer-to-peer method of exchanging tokens. This method is based on a specific smart contract* called "hashed TimeLocked Contracts" (HTLCs). The principle is based on the guarantee that the two people exchanging tokens will actually do so. The smart contract requires the recipient of a payment to acknowledge receipt of the payment within a specified time by generating a cryptographic receipt. If this is not done, the recipient loses the right to access the funds, which are then returned to the sender.

Automated market maker : a protocol for calculating the exchange rate between two crypto-assets automatically. The automated market maker is the basis of all DEX (Decentralized Exchange), and allows its users to exchange crypto-assets with each other on a peer-to-peer basis, without going through a third party. The first platform to use this principle is called Uniswap.

Blockchain Explorer : Every public blockchain has a command line interface (CLI) to display the history of transactions on the network. In order to allow anyone to access the history of these transactions, most public blockchains also offer a "browser" that can be accessed via a web browser to display the desired information in a user-friendly way. See for example https://www.blockchain.com/explorer.

Merkle tree or hash tree : In computer science and cryptography, a Merkel tree is a data structure containing a summary of information from a large volume of data. The principle of a hash tree is to be able to verify the integrity of a set of data without necessarily having all of them at the time of verification. To do this, within a series of data, one of them is hashed. This hash will be concatenated with a hash of a second data from the same series. This concatenation will create a

parent hash. The process is repeated with the parent hashes until a unique hash is reached, called the top hash. Thus, to check the integrity of a data, it is enough to know the hash of the data which are connected to it.

DAO - *Decentralized Autonomous Organization* : A DAO is an organization of people powered by a computer program that provides governance rules to the community without centralized direction. These rules are transparent and immutable because they are encoded in a blockchain protocol.

dApps - *Decentralized Application* : For Andreas Antonopoulos, a decentralized application includes “one or more smart contracts deployed on one or more blockchains, a transparent user interface, a distributed data storage model, a peer-to-peer message communication protocol and a decentralized name resolution system. Once deployed on a public blockchain like Ethereum, the computer code of a decentralized application (dApp) cannot be deleted or stopped so that anyone can use its functionality. This means that even if the person or group of people who created the application disappears, the decentralized application will continue to function.

Decentralized Finance - *Decentralized Finance (DeFi)* : DeFi is an ecosystem of applications that replicate financial services on a blockchain. They allow anyone with the means and regardless of country or nationality to borrow, lend and invest, insure and trade crypto-assets without going through an intermediary, transactions being secured through the use of a blockchain and *smart contracts*.

Delegated Proof of Stake : A consensus mechanism that reduces the number of nodes on a blockchain and relies on the election of miners (the validators of blocks of transactions on a blockchain) who have tied up funds (stake) in crypto-assets in a blockchain in proportion to what each has.

DEX - *Decentralized Exchange* : A decentralized exchange (DEX) is a type of crypto-asset exchange that operates on a peer-to-peer basis and without intermediaries. Unlike centralized exchange platforms (CEX), such as Binance or Kraken, exchanges are operated directly between users, reducing the risk of theft caused by exchange hacking, price manipulation and ensuring greater anonymity.

Ethereum Virtual Machine : a unique virtual entity that allows the execution of all smart contracts* of all decentralized applications (dApps) and all decentralized autonomous organizations (DAOs) developed on the public blockchain without Ethereum permission. Indeed, Ethereum can be compared to a distributed state machine. A distributed finite automaton is a mathematical construct that can change its state. Ethereum has two states: a state that allows it to manage all accounts and balances of payments made with its native crypto-asset, Ether;

and a state called “machine state”. This “machine state” changes from block to block, so as to execute the smart contracts* that are in it. The changes of the machine state are done according to a set of rules. These specific rules for changing state from block to block are defined by the Ethereum Virtual Machine (ethereum.org).

Feature phone : A cell phone with the basic technical characteristics of a smartphone.

Fork (hard / soft) : In computer language, a fork consists in creating a new software from the source code of an existing software. A soft fork brings changes to the blockchain concerned that will only apply in the future, whereas the changes introduced by a hard fork are also valid for the past. A hard fork consists of rewriting the source code of a blockchain protocol after its launch.

Fiduciary money - *fiat money* : Money in the form of coins and banknotes, whose face value is higher than its intrinsic value. The trust (fiducia in Latin) that the user places in it as a value of exchange, a means of payment, and therefore as a currency is based on the legal tender assigned by the State.

Hash (function of) : mathematical function that transforms any content into the form of a hexadecimal number. The slightest change in the content causes the hashed number to become completely different.

The advantage of a hash function is that it only applies in one direction: the resulting hash does not allow you to go back to the original content, but you only need to hash the content again to check that the resulting hash is identical, which proves that no modification has occurred. The blocks of transactions of a blockchain are hashed as they occur and allow us to have the guarantee that they have never been modified since the first transaction.

ICO - *Initial Coin Offering* : Issuance of tokens exchangeable for crypto-assets to raise funds from a community. Unlike an IPO (Initial Public Offering), which allows a company’s shares to be listed on a stock market, an ICO is not regulated by a financial regulator.

Identity Wallet : Wallet composed of verifiable credentials. See Verifiable Credential.

IPFS - *InterPlanetary File System (IPFS)* : A distributed peer-to-peer file system whose objective is to store information and data in a decentralized, secure and confidential manner, thus protecting against all forms of censorship. Today, a search for information on the web consists of asking a search engine “where is the content” in order to identify the URL of the server where it is located; a search in IPFS consists of asking the system “the content you are looking for”, identified by a unique and permanent cryptographic hash.

Created in 2014 by Juan Benet, IPFS is an open source protocol that could develop alongside the HTTP protocol invented by Tim Berners-Lee in 1991.

Lightning Network : A peer-to-peer payment protocol built as a second-layer application on the Bitcoin blockchain that enables extremely fast bitcoin transactions, on the order of one million per second, at virtually no cost and with no energy expenditure, since transaction validation does not require proof-of-work mining. Since 2015, players in the Bitcoin community, including Lightning Labs, Blockstream and ACINQ, have been working on this protocol, which provides one of the answers to Bitcoin's order-of-magnitude (scalability) problem, which, as a reminder, can only process 7 to 10 transactions per second. The Lightning network has been operating since May 2018.

Mainnet / Testnet : The term mainnet is used to describe when a blockchain protocol is fully developed and deployed, and crypto asset transactions are disseminated, verified and recorded on the blockchain. The term testnet describes the development and testing environment before the mainnet is launched.

Miner : A validator of transactions on a blockchain. The miner is paid in the native crypto-asset of the blockchain within which he validates transactions.

Mnemonic phrase - *Seed Phrase* : A sequence of words (usually 12 or 24) allowing the retrieval of a cryptocurrency wallet from any device.

Mining pool : An association of miners cooperating to carry out the work of validating transactions within a blockchain. The gains made by the jointly acquired machines are shared among the members of the mining pool.

NFT (Non-Fungible Token) : literally non-fungible tokens. In contrast to two fungible coins, i.e., coins that cannot be differentiated (a one-euro coin is similar in all respects to another one-euro coin), an NFT is a unique token, and this uniqueness makes it lose its fungible character. An NFT executes computer code stored in *smart contracts** that comply with different standards such as ERC-721 on Ethereum.

On-chain/Off-chain : When a transaction is on-chain, it means that it is recorded in a blockchain. An off-chain transaction, on the other hand, takes place outside the blockchain. For example, transactions on the Lightning Network (see above) take place outside the Bitcoin blockchain and are called off-chain.

Oracle : in the field of blockchains, an Oracle is a source of information from the physical world to which one or more *smart contracts** are connected and whose parties agree on the reliability of the data.

Examples include IATA for data related to airline flights or Météo France for data related to meteorology (precipitation, frost, snow, etc.). When used in decentralized applications, the data from an oracle can be used to trigger the terms of a smart contract. For example, a parametric insurance will automatically reimburse a farmer in case of a weather disturbance whose data is certified by an oracle.

Stablecoin: a crypto-asset collateralized by a fiat currency or another crypto-asset, respecting a fixed parity against it. For example, MakerDAO's Dai stablecoin has a fixed parity to the US dollar : 1 Dai = 1 USD. There are three types of stable crypto-assets, corresponding to three ways to respect this parity. On the one hand, centralized stablecoins are created from reserves of fiat currency (e.g. US dollars) deposited by users in the application and kept in the bank by the service operators. In fact, the amount of crypto-assets put into circulation corresponds exactly to the reserves of fiat money. On the other hand, decentralized stablecoins are created from reserves in other crypto-assets. Thus, stable crypto-assets are created based on the dollar value of other crypto-assets held in reserve. MakerDAO's Dai, previously mentioned, is a decentralized stablecoin. Finally, there are algorithmic decentralized stablecoins, which are created based on the variations of another crypto-asset created by the same service operator. This other crypto-asset will be issued and redeemed so that it fluctuates in price against the U.S. dollar. Its dollar value will condition the creation of the stablecoin. This process has been much criticized, especially during the collapse of the algorithmic stablecoin Luna/Terra.

Proof-of-stake : A method for validating blocks of transactions on a blockchain devised by Scott Nadal and Sunny King in 2012. This method requires the user to prove possession of a certain amount of crypto-assets in order to claim to be able to validate additional blocks in said blockchain and to be able to collect the reward for adding these blocks. This consensus mechanism consists in solving a computer challenge called minting, operated by "forgers". It does not require powerful computer hardware, consumes little electricity and fits on a nano computer like the Rasperry Pi. To validate a block of transactions, the forger deposits a certain amount of crypto-assets and receives a reward when he validates a block for blocking this capital. If the forger carries out a computer attack by inserting fake blocks of transactions into the blockchain, the community, from the moment it realizes this, could carry out a hard fork*, which would result in the loss of the attacker's deposits. Vitalik Buterin, co-founder of Ethereum explains: "the philosophy of proof of stake summarized in one sentence is not "security comes from the energy spent", but rather "security comes from the economic losses generated by an attack"".

Proof of Authority (PoA) : Proof of Authority is a consensus algorithm that designates a small, identified number of actors within a blockchain network with the power to validate transactions and update

the registry. This consensus algorithm is often implemented on private or consortium blockchains. The interest for these actors, often banks, is to gain auditability and thus reduce and optimize the costs related to their coordination.

REDD + *Reducing Emission from Deforestation and Forest Degradation*: a mechanism developed by the stakeholders of the United Nations Framework Convention on Climate Change (UNFCCC), which creates a financial value for the carbon stored in forests by providing developing countries with incentives to reduce emissions from forest lands and invest in sustainable low-carbon development strategies. Beyond deforestation and forest degradation, REDD+ includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

RFID - *Radio Frequency Identification* : refers to a method of remotely identifying data embedded in objects or products in the form of a tag and comprising an antenna associated with a microchip.

Satoshi : A Satoshi is the smallest divisible unit of a Bitcoin, the 8th digit after the decimal point. One satoshi is therefore equal to 0.00000001 bitcoin. The name is inspired by the name of the person or group of people who published the founding white paper of Bitcoin in 2008,

SDK - *Software Development Kit* : A set of programming tools for designing and developing software or applications.

Sidechain : A sidechain is a secondary or parallel blockchain designed to operate alongside a primary, public blockchain, in order to increase its capabilities and overcome its inherent limitations, particularly in terms of scalability. The use of a sidechain makes it possible to process transactions without using the primary blockchain, for example, to perform specific calculations, or to process smart contracts in a private environment before the data is recorded in a primary blockchain, such as Bitcoin or Ethereum.

Smart Contract : According to the Ethereum.org website, *smart contracts** are “applications that run exactly as programmed, without the ability to stop them, uncensorable, without possible fraud and without third-party interference.” The advantage of these contracts is that they are autonomous, automatic and replicated in all the nodes of a blockchain, and that their execution does not require a trusted third party to guarantee their validity. Several public blockchains allow the implementation of smart contracts, including Ethereum, Polkadot, Tezos, Stellar and Solana.

Staking : Staking consists in immobilizing and locking tokens in a *smart contract**. The protocol randomly assigns to one of the participants the right to validate a block of transactions and receive a token reward. The “proof of stake” mechanism encourages

users to immobilize their tokens, the probability of being chosen to validate a transaction block being proportional to the number of locked tokens. The more tokens a user has locked, the greater the probability of being chosen to validate the transaction. If a user tries to write false transactions in a block, he loses his locked tokens and is banned from the network.

Token / Tokenization : A token is a digital unit (an asset) exchanged on a blockchain. Bitcoin is the token of the Bitcoin blockchain. Ether is the token of the Ethereum blockchain. By extension, the term “tokenization” refers to the idea that any asset can be digitally represented and traded via a blockchain.

Verifiable credentials - (VC) : digital proofs delivered by a third party (called issuer) to a user (holder) proving a characteristic of his identity (his age, his place of birth, ...). Thus, by presenting these verifiable credentials to a verifier, the user can transmit the information strictly necessary to access a service while remaining in control of his personal data.

Wallet (of crypto-assets) : in terms of crypto-assets, a wallet is a device that can take the form of a physical medium, a computer program or a service, and whose purpose is to store the public and/or private keys of crypto-assets. This process of storing the private key, known only to the owner of the wallet, allows its holder to sign transactions and to prove to all the peers of the blockchain network that he is the owner of the crypto-assets used.

Zero Knowledge Proof (ZKP) : Zero Knowledge Proof is a cryptographic method that allows one person (the prover) to prove to another person (the verifier) that he or she is in possession of certain information without revealing it to the verifier. In other words, zero-knowledge evidence allows evidence of facts about personal data to be presented without revealing that personal data. Zero-knowledge proofs were first conceived in 1985 by Shafi Goldwasser, Silvio Micali and Charles Rackoff in their article “The Knowledge Complexity of Interactive Proof-Systems”.

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bonjour@blockchainforgood.fr

BLOCKCHAINS & SUSTAINABLE DEVELOPMENT

Can blockchains accelerate the achievement of the Sustainable Development Goals in a significant and sustainable way? Is it possible to reconcile certain blockchains and the energy consumption required for their operation with the Sustainable Development Goals? Are there public blockchains whose transaction security does not have the same energy impact?

The diversity of use cases for “blockchain for good” projects seems to result from natural convergence of the principles of transparency, traceability, collaboration and decentralization that underlie these distributed registers and which are implicit in the Sustainable Development Goals. Can the global health crisis, triggered by the Covid-19 pandemic and the awareness of the value and resilience of decentralized models serve as an accelerator for the use of this class of technology?

The second edition of this report “Blockchains & Sustainable Development” has been an opportunity to collect information about some 700 blockchain projects - each of which is related to the pursuit of one or more of the Sustainable Development Goals.

The analysis of numerous projects, some of which have already gone beyond the simple proof-of-concept stage, allows us to validate the relevance and efficiency of models based on a technical architecture that distributes trust among its users, according to predefined rules, and a governance without head or center, heralding new forms of social interactions.