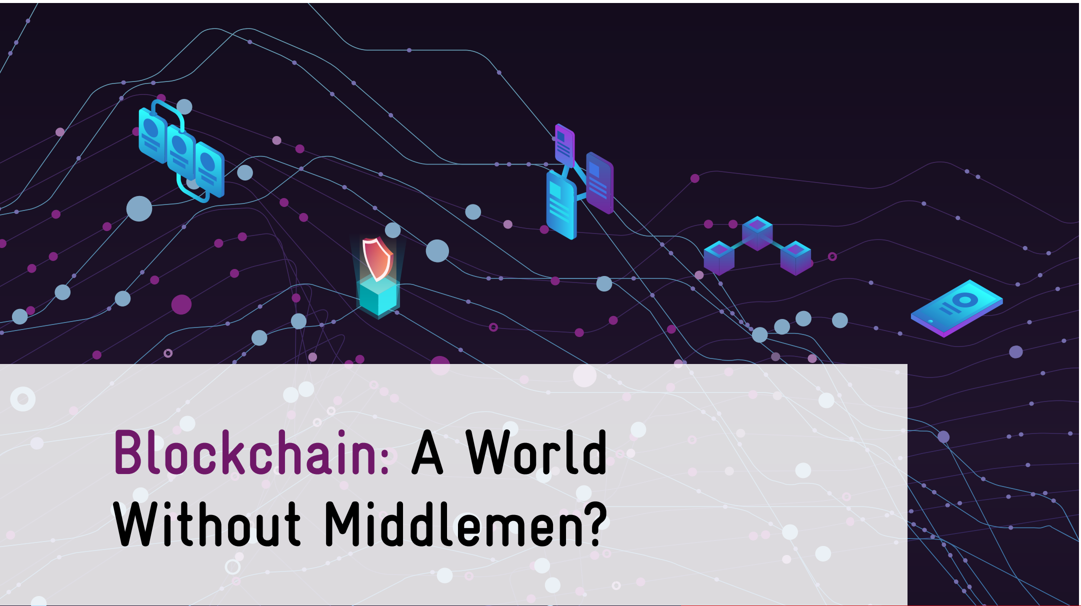

Blockchain: A World Without Middlemen?

Promise and Practice of Distributed Governance

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Foreword

Connecting bits and atoms

Crypto-asset valuations peaked in late 2017, giving way to more sobering views on digital currencies. The expectations regarding the underlying technology – blockchain or distributed ledger technologies (DLT) – seem to follow a similar pattern: after much praise, the blockchain community had a number of critical realisations in 2018 regarding the degree to which DLT can actually add value in real life applications. To date, a few simple applications like timestamping and cross-border remittances have shown practical success, while more complex DLT applications remain at early conceptual stages with low adoption rates compared to other Internet-based services.

For us at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and its Blockchain Lab, we believe it is too early to reach a final verdict on DLT in the realm of international development. We have no doubt that digital transformation has come to be the single most impactful driver of change worldwide, and a massive accelerator of the megatrends of industrialisation and globalisation. Within our mandate of working towards the achievement of the Sustainable Development Goals (SDGs), we use the potential of technological innovations in the transformation of economies, societies and governmental bodies. This includes assessing the promises of frontier technologies such as blockchain. The reasons why DLT in particular raised our attention are threefold:

First, *blockchain is an incentive machine*. Today, Bitcoin's proof-of-work system is a lamentably effective incentive for wasting energy, with its mining activities currently amounting to 0.21% of global electricity consumption. We want to ask: what would it take to turn this around and build an incentive machine for societal goals, such as CO_2 reduction instead? How can blockchain become a carrot for positive social change where sticks fail? And might tokenised social impact marketplaces one day serve as a global incentive for the advancement of the SDGs? Second, *blockchain is a decentralisation machine*. Cutting out gatekeepers and middlemen can help increase efficiencies and improve competition in markets. Between nation states, blockchain could act as an automated enforcement mechanism for cross-border transaction agreements, for instance with regard to trade or water. Third, *blockchain is an accountability machine*. Transparency in public procurement is one of several examples of how DLT can be used as a tool to implement checks and balances for governmental action, which in turn serves to restore much needed faith in democratic institutions.

Before reaching a conclusive answer on the potential of blockchain for development purposes, we believe it is worthwhile to implement a number of proofs-of-concept and pilot projects for the most promising use cases. These will not only help us determine the practical benefits of DLT and acquire much-needed implementation know-how, but also pave the way for successful scaling efforts.

With this in mind, we developed this publication as guidance for practitioners from government, the private sector and actors from international cooperation and development. We are aware that no one-size-fits-all approach exists, and in many cases individual evaluations will be needed, taking into account both the specific context of application and the increasing convergence of blockchain with other technologies such as sensor networks, AI, fintech applications and cloud computing. Either way, we know that in the decades to come, the digital transformation will not cease to demand from us a constant updating of both our mindset and understanding. I thank you for joining us on this learning journey.

Dr. Christoph Beier
Vice-Chair GIZ Management Board

Dr. Dirk Aßmann
Director General Sectoral Department

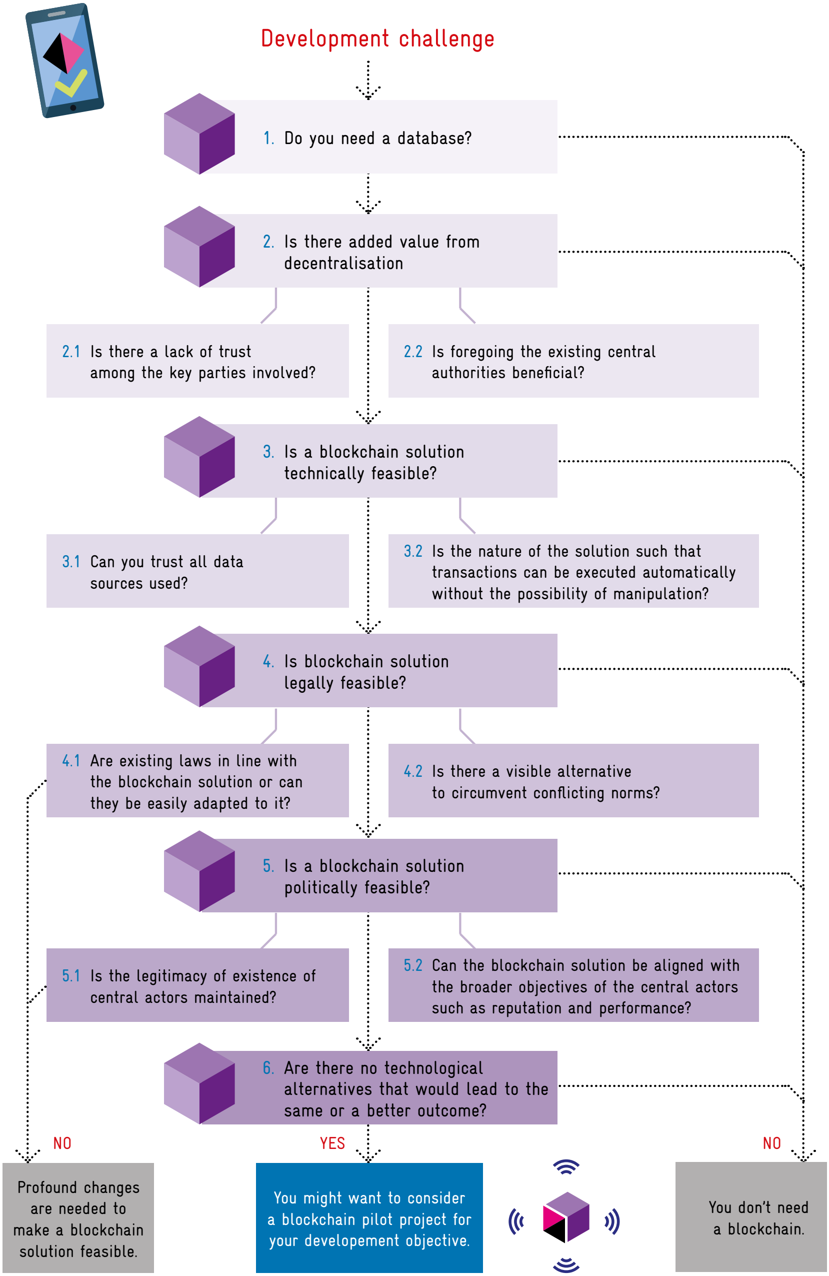
List of Acronyms used

AI	Artificial intelligence
AML	Anti-money laundering
API	Application programming interface
CSR	Corporate social responsibility
DAG	Directed acyclic graph
DDoS	Distributed denial-of-service
DLT	Distributed ledger technologies
ECTS	European credit transfer system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IoT	Internet-of-things
(e)KYC	(electronic) Know your customer
LPWAN	Low-power wide-area network
MIT	Massachusetts Institute of Technology
NGO	Non-governmental organisation
PDF	Portable document format
QR	Quick response
SDG	Sustainable Development Goal
SICA	Sistema de la Integración Centroamericana
UNICEF	United Nations International Children's Emergency Fund
UNOPS	United Nations Office for Project Services
US	United States
VAT	Value added tax
ZSL	Zero-knowledge security layer

Acknowledgements

This report would not have been possible without the contributions and critical input of many people. We would especially like to thank Marc Johnson, Pete Johnson, and Andrew Glidden for comments on previous drafts of this publication. Moreover, our thanks go to Andreas Lange for his advice on the land registries use case, Dennis Horch and Karola Hahn for their guidance on the education credentials section as well as Lilian Laurisch and Jörg Michael Baur for their inputs regarding the energy use case. We would also like to thank Sebastian Geschwind, Joséphine Quioc, Eren Atarim and Theodor Beutel who supported our research, Phoebe Blackburn for proofreading and FLMH | Labor für Politik und Kommunikation for the design of this publication.

A 'HOW TO' Guide to Blockchain for International Development Practitioners



CHAPTER 1

Introduction

It is December 2017 and the *Legal Tech of Future Law* conference in Vienna is in full swing. The excitement for blockchain has reached its momentary zenith. More than 300 guests listen attentively when the start-up Bitfury presents a blockchain pilot implemented with GIZ for the Georgian National Agency of Public Registry. Its goal? Making the registration and administration of land titles in this Eurasian country of the Caucasus region more efficient, secure and, above all, intelligible to every citizen. In Georgia, as in many other countries worldwide, land registration can be a cumbersome, time-consuming and costly process. Plus, many states are struggling with corruption, dubious land transactions and land grabbing – with often far reaching socio-economic consequences. Secure land ownership for both women and men is key for improved household income, food security and trust in governmental institutions, among others. It is therefore unsurprising that the decentralised and transparent nature of blockchain has come to present a golden opportunity for many individuals. Over one million land titles have been recorded on a distributed ledger in Georgia by now, accessible and verifiable by citizens, at any given time and from anywhere. Clearly, we seem to be heading towards a more decentralised future.

Note on terminology: 'blockchain' and 'distributed ledger technology' (DLT)

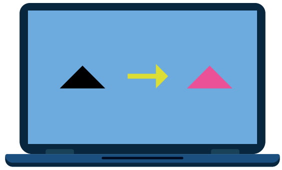
Technically, blockchain technology is only one specific type of distributed ledger technology. There are other types of DLT, not relying on a 'chain of data blocks' as the underlying technical data structure (such DLT are called blockchains). However, in the public discourse, the term 'Blockchain' is now widely used as a catch-all for all sorts of distributed ledger technology. We apply the same principle for this document and use both terms interchangeably.

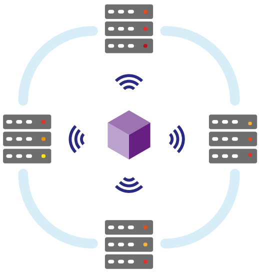
The early days of experimentation for Georgia's public registry have shown that blockchain is more than just the cryptocurrency Bitcoin. Together with other first pilots conducted across the globe, the technology is increasingly sparking entrepreneurs' imagination and gaining policy makers' attention when it comes to rethinking existing institutions. Given that blockchain questions one of the foundations of our modern societies, namely, the role of trusted, centralised third parties, the excitement surrounding it is not completely unwarranted. Our daily lives are largely organised around uncertainty and trust issues – and rightly so. We depend on financial institutions for very practical things such as paying our rent or buying food, but we also often rely on trusted middlemen like governments to access critical services such as education, insurance, and healthcare. Yet, putting our trust in other people's hands comes at a cost, and not only in monetary terms. The mechanisms we have set up to create trust among people are often complex and ponderous as well as prone to corrupt, greedy and malicious actors. Against this backdrop, the promise of blockchain – or as some say the 'trust machine' – has obviously engendered massive expectations. From disrupting the banking industry to rendering central governments completely obsolete, the incessant buzz accompanying the technology has spurred many dreams and fears. As of today, however, we must realise that real-life adoption of DLT applications remains very low compared to other Internet-based services by looking at metrics such as monthly active users, blockchain-enabled revenues and numbers of transactions.

Therefore, we believe it is time for a reality check. Blockchain is certainly not a panacea.

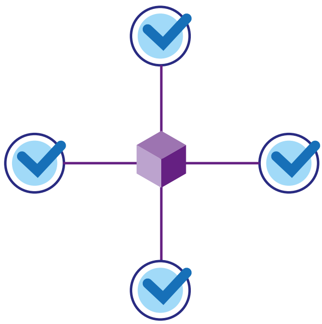
Therefore, we believe it is time for a reality check. Blockchain is certainly not a panacea. Thanks to its distributed architecture, it can be a valuable tool to match supply and demand whilst bypassing middlemen and to settle transactions on an immutable ledger. However, full decentralisation comes at a cost. Compared with long-standing centralised and institutional practices, blockchain is often less effective on achieving outcomes such as data quality or good user experience. As an incentive machine, blockchain is a technology using carrots instead of sticks. It is hard to exert coercive power on a public ledger because anyone can create new identities, opt in and opt out again at any time. Having said that, there is ample room to explore new use

A transaction is requested.





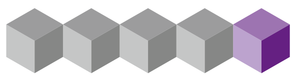
The requested transaction is transmitted to all nodes of a blockchain network.

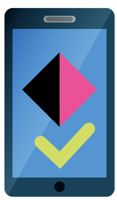


All individual nodes approve the requested transaction.

After approval the validated transaction is transformed into a block of data.

The new datablock is added to a blockchain. From now on it cannot be altered.





The requested transaction is completed.

cases, question the function of existing centralised gatekeepers and middlemen, and reconsider the way citizens, companies and governments interact.

Today, ten years after the publication of Satoshi Nakamoto's whitepaper for Bitcoin, the majority of DLT applications are still centered around speculative crypto-investments. Our focus will be a different one. We are guided by the question of what added value decentralised applications can have for economies and societies at large. We define added value not merely in terms of revenues, profits or GDP, but in the broader sense outlined by the United Nations Sustainable Development Goals. The scope of blockchain applications under consideration ranges from simple timestamping tools for public sector accountability all the way to the 'tokenisation' of the SDGs themselves. While simple applications like timestamping or cross-border remittance payments have shown successes in practice, many of the more ambitious and complex solutions remain in their early conceptual phase. In order to test their viability in real-life environments, proof-of-concepts and pilot projects have yet to be implemented.

> **Hence, with this study we want to make a step towards equipping international development experts with the necessary knowledge about what blockchain is – and isn't.**

For the most promising use cases to acquire this much needed real-world exposure, we believe in the merits of cross-fertilization between the tech world and practitioners of the international development community. Hence, the aim of this study is to make a step towards equipping international development experts with the necessary knowledge about what blockchain is – and what it is not. We talk about the implications DLT has for sustainable development, and how to best assess its added value for a given development project.

In this endeavour we align ourselves with the *Principles for Digital Development*. These Principles, endorsed by GIZ in February 2018, comprise a set of good practices and guidelines, such as user-centered design, open standards and collaborative development, which were established to support development practitioners in promoting effective technology-enabled development work. The use of blockchain in certain projects is criticised for being 'a technology in search of a problem'. When designing proof-of-concept or pilot projects we shall instead take – in line with the Principles – a user-centered approach and look for sound contextualisation and societal impact.

This study is structured along the following lines: after the introduction, **CHAPTER 2** will provide a 'blockchain 101', outlining the key characteristics of the technology, its differences to traditional databases and the different types of existing blockchains. In **CHAPTER 3** we will discuss five promising use cases that suggest new pathways for the advancement of the SDGs. **CHAPTER 4** will offer governments, development practitioners and other stakeholders an initial assessment framework to evaluate whether deploying blockchain for their development objective is advisable by answering some core questions in terms of project design and implementation. **CHAPTER 5** will provide a perspective for the way forward for blockchain in international development cooperation.

CHAPTER 2

What is blockchain about?

An introduction to distributed ledger technology

Evaluating the use of blockchain technology in international development cooperation can seem like a daunting task. Mountains of confusing technical jargon make it difficult to distinguish between hype and reality. Fortunately, obtaining a degree in computer science is not a prerequisite to being able to constructively assess blockchain-for-development use cases. That said, it is worth putting in a bit of time and effort to understand a few essential terms that are frequently employed by blockchain enthusiasts.

Ledgers

Since ancient times, traders have used books of lists, or ledgers (in German: 'Register') to keep track of the goods they bought, sold and traded along their trade routes in order to reconcile the goods sold with payments received. By providing a simple and reliable mechanism for keeping track of assets and payments, ledgers became a foundational instrument for organising modern societies and their economic activity. Modern ledgers document things as diverse as account balances, land titles, copyrights or votes. They establish a reliable record of identities, ownership rights, asset flows and provide documentary support for complex contractual agreements.

Distributed ledgers

In a distributed ledger, the list of facts one wants to keep track of is not exclusively stored in one central place. Instead, multiple copies of the same ledger are maintained simultaneously by different parties. In other words – although ledgers as a concept are logically unitary (there is only one ledger) – organisationally-speaking, a distributed ledger is physically decentralised. Many entities in the network maintain a copy of the same ledger so that the destruction of one copy does not result in the destruction of the entire ledger.

> **In a distributed ledger, the list of facts one wants to keep track of is not exclusively stored in one central place. Rather, multiple copies of the same ledger are maintained by different parties simultaneously.**

Distributed ledger technology

Distributed ledger technologies are designed to ensure consensus concerning the current state of the ledger among all network participants so that everyone sees the same data at the same time. To put it more precisely:

> **DLT are shared ('distributed' or 'decentralised') digital ledgers that use cryptographic algorithms to verify the creation and transfer of digitally represented assets or information over a peer-to-peer network. They operate via an innovative combination of distributed consensus protocols, cryptography and in-built economic incentives.[1]**

The digitally represented assets being tracked on the ledger could be money, stocks, bonds or other financial assets, physical assets such as titles to land or vehicles, or intangible assets such as rights to data or to the control or use of artistic creations (music, videos, paintings, etc.). The DLT's consensus mechanism ensures that it is neither possible to create unauthorised copies of the ledger's digital entitlements (forgeries) nor to sell them simultaneously to more than one party without the other party's knowledge ('double spending'). This ensures the entries on the ledger are always up-to-date and verified against other data on the ledger.

This method of distributed consensus-building is a revolutionary development in the history of modern computing, and it has important implications for the future organisation of societal and economic entities. DLT adds a new layer of trust into the Internet, offering a new level of data sovereignty and for the first time, making it possible to create digital assets that are both scarce and non-falsifiable. It is for this reason that the first fully functional example of a blockchain – Bitcoin – emerged in the field of currencies. Prior to Bitcoin, it was impossible to create a non-centralised digital currency that could neither be double-spent nor be counterfeited. In a blockchain structure like that of Bitcoin, this is achieved by applying a data structure consisting of chains of blocks, digital signatures and an incentive mechanism called 'proof-of-work':

> **A copy of all transactions is stored as an immutable chain of blocks, which are digitally signed by all parties to the transaction, affirming the integrity of each individual transaction and the ledger as a whole. In a blockchain structure like that of Bitcoin, nodes that wish to have their version of the truth considered by the network must engage in a process known as mining, through which they validate and establish consensus over chunks of transactions. In this process, nodes have to solve a cryptographic puzzle as a proof of work, which requires expensive computing hardware and even more expensive electricity. Even if an attacker decided to create enough nodes to impose a false consensus on the network, the mining costs for this attack would outweigh the potential benefits. Hence, the Bitcoin's blockchain protocol sets incentives in such a way that the benefits of cheating are far outweighed by the costs.[2]**

DLT adds a new layer of trust into the Internet, offering a new level of data sovereignty and for the first time, making it possible to create digital assets that are both scarce and non-falsifiable.

A more detailed description of the inner workings of Bitcoin and other DLT would go beyond the scope of this document. There are, however, many excellent sources for both technical and non-technical audiences explaining in detail how Bitcoin and similar DLT work, e.g.:

How Bitcoin Works in 5 Minutes (quick overview)

Ever wonder how Bitcoin (and other cryptocurrencies) actually work? (detailed non-technical introduction)

Bitcoin White Paper (detailed technical introduction)

Ethereum White Paper (detailed introduction)

Smart contracts

While cryptocurrencies were the first practical application of blockchain technologies, they are by no means the only one. Another important feature of certain blockchains is that they can be used to create so-called 'smart contracts'. These can be used to automate the performance of simple tasks in response to predetermined events.

Imagine, for example, that your home is equipped with an Internet-enabled receptacle for accepting fresh milk deliveries from a local creamery. The receptacle could be programmed with a smart contract to scan the QR code from a milk bottle placed in the receptacle and automatically transmit the required payment to the creamery upon delivery. In theory, smart contracts can be used to carry out such transactions among all kinds of Internet-of-Things (IoT) devices and for all kinds of purposes. Smart cars can pay their own parking fees, smart solar panels can charge neighbouring houses for providing them with electricity; the possibilities seem endless.

Smart contracts define the rules and penalties around a digitally represented agreement and automatically enforce the obligations arising out of that agreement. In theory, any application or automated transaction that runs on a conventional computer can also be executed on a distributed consensus network. The collective power of the network ensures that the programme code (the rules which represent the terms of the parties' agreement) is executed in the exact same way as agreed beforehand among all parties. This makes it unnecessary to involve a third party to monitor and ensure the execution of the rules, which, as a result, leads to reduced transaction costs.

> **Smart contracts define the rules and penalties around a digitally represented agreement and also automatically enforce the obligations arising out of that agreement.**

As the milk delivery example shows, however, smart contracts are neither truly smart nor truly contracts. They are not smart in the sense that they merely carry out pre-programmed instructions. If the delivery person was to place an empty milk bottle into the receptacle, the scanning of the QR code would result in the receptacle paying the creamery even though no milk was delivered. Likewise, the fact that an agreement has been reduced to a set of coding parameters does not necessarily confer upon it the status of a legally binding contract. This can be seen by simply replacing the word 'milk' with the word 'cocaine' in the delivery example. A smart contract programmed to verify and pay for cocaine deliveries would not constitute a legal contract, since contracts for the purchase and sale of illegal goods are void as a matter of law.

Last but not least, as smart contracts boil down to computer code, they are only as 'smart' as the code that executes them. If there is a bug in the code, the contract may not execute in accordance with the expectations and wishes of the parties. In such cases, off-chain intervention may be necessary to correct the mistakes or modify the contractual agreement, and the advantages gained from automation may be lost. Smart contracts, in other words, are only as good as the programmers who code them.

With this basic terminology in mind, let us now look at the key properties of distributed ledgers in comparison to ordinary databases. This is crucial to understand when and why employing a DLT might make sense in an international development context.

DLT vs. ordinary databases

DLT differ from ordinary databases or systems in several important respects:

→ *Physically decentralised* – DLT are physically decentralised, which means that copies of the same data are stored in different locations. If one node in the network goes down, the ledger remains accessible to all other nodes in the network. In fact, unless all nodes in the network go down, the integrity, availability and operability of the ledger as a whole is maintained. This is a strong resilience property. DLT have **no single-point of failure**, which makes them less susceptible to either catastrophic cyber-attacks or real life threats such as power outages or natural disasters.

→ *Distributed consensus mechanism* – at the core of blockchain technology lies a consensus mechanism that keeps all copies of the ledger up-to-date and in sync with one another. Most importantly, it employs modern encryption technology and game theoretic incentives to keep inaccurate or potentially fraudulent transactions out of the database. This is why DLT is sometimes referred to as **'trustless'** technology or **'trust machines'**[3] since there is no need to trust any party participating in the network. Instead, all participants place their collective trust in the robustness of the consensus protocol which governs their interactions with one another. As long as the consensus mechanisms make it either computationally or economically infeasible to 'game the system' for personal gain, all users can enjoy a high degree of confidence that the system will operate as expected.

→ *Data integrity* – once a transaction is confirmed by the participating parties and written into the ledger, the protocol does not allow for any changes to be made after-the-fact. Consequently the ledger's utility is partly derived from its **immutability**. The particular data structure of DLT ensures the integrity of each individual ledger entry and the accuracy of the ledger as a whole. Any attempt to alter the data ex-post would be rejected by the consensus rule, and the attempt itself would become visible to all participating parties.

→ *Shared governance* – in a public distributed ledger, there is no central entity, e.g. an administrator, managing the ledger. Since there is no central party (no gatekeeper), there is no way to prevent anyone from participating. This is why public blockchains are often referred to as **open**. An important corollary that follows from this is that fully public distributed ledgers are **censorship-resistant**. The various parties participating in the ledger all help to keep one another honest by checking each other's work, but they do not have the power to prohibit one another from contributing to and using the ledger.

You may have noticed that the last bullet point speaks of 'public DLT'. As this reference hints, there are actually numerous different types of DLT, for example with regard to accessibility or consensus mechanisms. Some share many characteristics in common with centralised database systems, others less. The basic terminology and concepts introduced so far can be thought of as applying in a general way to most DLT. Still, appreciating the nuances is important. The following section therefore presents the main types of DLT and their respective strengths and weaknesses.

Types of DLT[4]

The structural properties of DLT very much affect the technical feasibility of the applications that can be built on top of them. Understanding these structural features thus constitutes a necessary prerequisite to being able to evaluate potential DLT use cases in the international development context. While 'blockchains' such as the Bitcoin blockchain are the best known type of DLT, in practice DLT come in several different types, and it is important to be able to distinguish between them.

Public-permissionless blockchains

Public-permissionless blockchains are blockchains in which anyone can, in principle, participate. With a little bit of technical know-how and an Internet-enabled device, anyone can connect to the protocol and either transact over the blockchain ('writer') or view the transactions taking place on the blockchain ('reader'). Likewise, anyone with sufficient time and resources can devote computing power towards performing the mathematical computations that secure the network ('miners') and receive new units of the blockchain's native digital token (e.g. Bitcoins on the Bitcoin blockchain, or Ether on the Ethereum blockchain) as a reward for this work. The protocol code is open-source, and decisions on changes to the code are adopted by majority consensus. In short, there are no formal barriers to the entry, use, or viewing of a public, permissionless blockchain.

Strengths of public-permissionless blockchains:

- *Ease of use and right of access* – low barriers to entry;
- *Relatively high security* – large amounts of energy and computing power are devoted by financially motivated parties to maintain the security of the network;
- *Continuous public vetting* – bugs in the code are often spotted and fixed quickly because the code is open source;
- *Transparency/auditability* – all transactions that have ever occurred on the network can be viewed by anyone at any time, from the very first transaction to the most recent one.
- *No specific intermediary required for consensus* – agreement on the state of the ledger can be achieved without an intermediary confirming the state.

Weaknesses of public-permissionless blockchains:

- *Privacy* – in some instances personal privacy concerns may trump public accountability concerns when it comes to data storage and transmission (but note that some next generation public blockchains are already using advanced cryptographic techniques to enhance user privacy - see. e.g. Zcash and Monero);
- *Scalability* – the most popular public permissionless blockchains in operation today are capable of handling only between three and 20 transactions per second, as compared to more than 50,000 transactions per second in centralised networks such as Visa.
- *Costs* – the costs of processing a transaction (mining fees) often increase

as the network's usage rises, thereby making it cost-prohibitive to process microtransactions. Transaction fees are necessary in public-permissionless blockchains to protect against spam attacks bloating the blockchain to unmanageable size.

- *Energy consumption* – many of the most popular blockchains rely upon computationally heavy consensus mechanisms, which make them highly energy intensive to operate. As of January 4th 2019, the Bitcoin network's electricity consumption amounts to 0.21% of total world energy consumption. This means a single Bitcoin transaction consumes enough electricity to power 15.48 US households for an entire day.[5] However, it is important to note that there also exist consensus mechanisms other than the "proof-of-work" described above, such as "proof-of-stake", which are not based upon brute computational force and thus require much less energy.

Private-permissioned blockchains

In private-permissioned blockchains, only parties who have been granted access ('permission') may participate in executing, mining, or viewing transactions. Permissions may be managed separately, so for instance viewing could be open, but mining remains permissioned. The code may be either open or closed source, but in most cases it is maintained by developer teams seconded or contracted by the parties who have permission to participate in the chain. Private blockchains are a popular solution among consortiums of actors with shared interests. For instance Ripple aims to make interbank settlement processes faster and cheaper by connecting multinational banks via a single shared ledger.

Strengths of private-permissioned blockchains:

- *Higher scalability with smaller energy footprint* – since access to private chains is limited to a smaller number of trusted parties, the number of nodes participating in the network can be kept to a smaller number and the amount of computational work required to secure the network can thus be reduced;
- *Privacy* – privacy can be achieved by concluding confidentiality agreements among the approved participants.

- *Lower transaction costs* – the participants designated as transaction verifiers can be required to perform 'mining' (or confirmation) operations as a condition of participation, rather than in exchange for cryptocurrency rewards, thereby lowering transaction costs;
- *Higher control over information management* – designated parties can more easily control the access to sensitive information.

Weaknesses of private-permissioned blockchains:

- *Security* – private blockchains are not as broadly distributed as public chains, which implies increased cybersecurity risks;
- *Collusion/cheating concerns* – since the integrity of the ledger depends upon all approved participants acting in good faith, it is necessary to restrict access to trusted participants and to regularly audit and verify that these participants are indeed acting in accordance with the terms agreed;
- *Inefficiency* – from a technical and cost standpoint, it often makes little sense to use private blockchains among known, trusted parties, where more traditional networked-database solutions such as Oracle, MySQL, and NoSQL might well suffice at lower cost.

Hybrid blockchains

As the name suggests, hybrid blockchains combine some of the features of both public-permissionless and private-permissioned blockchains. A hybrid chain might, for example, be configured to be 'permissioned' with respect to the chain's miners but 'public' with respect to its readers and writers. Alternatively, a hybrid chain might use a combination of open-source and closed-source code. It might allow some users to view certain types of information and make certain types of transactions over the network while restricting others from doing so. Examples of well-known hybrid projects include R3's Corda, some of the Linux Foundation's Hyperledger projects, such as Hyperledger Fabric and Hyperledger Burrow, and various experiments being conducted under the umbrella of the Enterprise Ethereum Alliance.

Strengths of hybrid blockchains:

- *Customisability/flexibility* – ability to pick and choose design features according to the use case; e.g. different types of user can be given different levels of access and use rights; privacy and transparency features can be tailored to specific classes of users, actions, or categories of information; different types of security features and identity practices may be adopted for different purposes, etc;
- *Consortium-friendliness* – large multinational corporations and global financial institutions favour hybrid blockchains because of their customisability; hence they are often suggested for use cases in which several large entities wish to work together on a DLT project.

Weaknesses of hybrid blockchains:

- *Complexity & cost* – need for customised design makes them time-consuming and costly to build;
- *Non-interoperability* – high degree of specificity and customisation creates significant barriers to interoperability with other DLT (especially public-permissionless DLT);
- *Lock-in effects* – the promotion of customised, non-interoperable protocols can lead to lock-in effects and ultimately stifle innovation by inhibiting healthy competition among distributed ledger platforms, leading to rising prices for users over time.

DAG-based DLT architectures

There are a number of DLT employing Directed Acyclic Graphs, so-called DAGs (non-cyclic graphs, in which each edge is directed from an earlier edge to a later edge) to transmit and confirm transactions in an asynchronous rather than 'chained' way. They include Railblocks, Hedera Hashgraph and the IOTA Tangle. As an example, we will elaborate on the latter, currently Europe's largest DLT platform. IOTA was conceived as a lightweight protocol for the Internet-of-Things (IoT) environment to facilitate micro-scale machine-to-machine transactions among billions of connected devices. In contrast to blockchains, the Tangle has no dedicated 'miners'. Instead, each IoT connected device that transmits a new transaction to the network must perform the computational calculations necessary to confirm two other transactions as a pre-condition for having its own transaction confirmed.

Strengths of DAG-based DLTs:

- *No third-party fees* – because the consensus protocol does not rely on miners, there are no third-party transaction fees, which makes it feasible for users to send micropayments;
- *Scalability* – DLT designs in which each participant confirms the transactions of others (rather than relying upon miners to do so) could scale and become faster with the number of participants -- limited only by required data synchronisation and coordination efforts;
- *Partition tolerance* – a DAG-based DLT can split off from the main network for extended periods of time and continue to operate without Internet connectivity (e.g. over Bluetooth or theoretically even TV or radio bandwidth), then rejoin the main network at a later time once the Internet connection is re-established; this feature is of special interest in regions with limited Internet bandwidth and/or an unreliable electricity supply.

Weaknesses of DAG-based DLTs:

- *Susceptible to spam attacks* – IoT devices have very low computational power, making it relatively easy for malicious actors to bloat the size of the tangle and slow down the network's transaction confirmation rates by sending out spam transactions (DDoS attacks); this renders it necessary to deploy anti-spam measures which in turn require a degree of permissioned centralisation;
- *Centralisation of network* – currently, the architecture of IOTA requires a centralised coordinator, which comes with weaknesses associated with private permissioned chains or centralised databases. There are ongoing debates and research as to whether the functionality of the coordinator can be fully decentralised and made obsolete.
- *Partition tolerance* – while this concept has been outlined as a strength of DAG structures, it is important to note that partition tolerance is still largely theoretical and the ability to safeguard against malicious

actors is reduced significantly in this environment. Until proven at scale, this crucial concept should be treated as both a potential strength and weakness.

To summarise: distributed ledger technologies today come in a stunning array of shapes and sizes. Each has unique advantages and disadvantages, and it is important to understand these in order to evaluate the prospect of DLT being beneficially deployed in the context of international development cooperation.

CHAPTER 3

How can blockchain be used for sustainable development?

Transforming our world: the 2030 Agenda for Sustainable Development and distributed ledger technologies

Adopted in September 2015 as the successor framework to the Millennium Development Goals, the 2030 Agenda is a historic normative roadmap and universal pledge of all countries to *leave no one behind*. Capturing the hopes and aspirations of people around the globe for meaningful progress and change, the 17 Sustainable Development Goals enshrined in the Agenda seek to eradicate poverty, promote economic prosperity, social development and environmental protection by prioritising policies and investments that have long-term and sustainable impact. Although the consensus reached around the SDGs alone represents a significant step forward – for the first time ever an international development agenda calls for action by low, middle, and high-income states alike – the real work still lies ahead.[6] 2030 is approaching with great strides and the international community must exhaust all available possibilities to deliver on its promise.

Digitisation has been recognised as one of the key enablers and catalysts for the achievement of the Global Goals. Digital solutions have yielded comprehensive economic and social progress in recent years in both developed and developing nations. Accordingly, digital technologies are increasingly leveraged within and across countries for social good – may

Digital solutions have yielded comprehensive economic and social progress in recent years in both developed and developing nations.

it be in terms of improving food security and gender equality, combating climate change, increasing energy access, fostering public health, or boosting economic growth and development.

However, despite the many promises associated with emerging technologies, the potential impact of digitisation needs to be confronted with the realities in development contexts. An acknowledgement which certainly also applies to blockchain. DLT promises to change the interaction between individuals, companies and institutions, thereby pushing us to re-think the role of existing gatekeepers and middlemen. From the vast space of ideas and concepts as to how blockchain could benefit sustainable development, we prioritised five applications according to the following set of criteria: relevance, potential transformative impact, feasibility and maturity.

(i) Blockchained education credentials

The challenge

The value of education is just as intangible as the concept of education itself. It is a 'tool' to eliminate prejudice, unemployment and hunger. Its value is correspondingly high. In the light of increasing job fluctuation, more international mobility and migration as well as tech savvy job profiles, the trend in education is to move towards smaller units of learning scattered across an entire lifetime. Moreover, we are witnessing increased non-formal learning elements in today's career paths. All these tendencies are intensifying the need for verifiable and transferable qualifications that prove an educational history to educational institutions as well as to employers. This would especially benefit the employment prospects for those without access to formal education.

Ideally, we would therefore have a complete set of all our education credentials in a tamper-proof way at our fingertips, a sort of universal verifiable educational e-passport. However, this is far from the status quo as credentials come in all kinds of forms, fraud exists to various degrees, and validation, if any, relies on a wide spectrum of mechanisms with different levels of reliability. As an applicant to a university programme, for instance, we often have to request certified transcripts from schools and governments which takes time, requires fees and is often provided in a paper-based format. Besides, if certificates are lost or institutions are dismantled or unreachable, which is the case for migrants and refugees, there can be far-reaching consequences. Should they fail to provide a diploma of completed study, they might be prevented from continuing their education, getting a job or – in the worst case scenario – lose residency rights in their host country

Blockchaining education credentials

Distributed ledgers offer new avenues to store and verify credentials as digital records in a unified, portable, secure, tamper-proof and globally accessible manner. There exist various types of learnings which can be certified: from the totality of learning achieved to smaller units of learnings, the acquisition of a skill (level) or a concrete experience contributing to learning. Likewise, the blockchain-based credential management mechanism can take several forms: the most basic decentralised educational credential architecture is simple. In a first step, a trusted certifier admits accredited institutions, for instance universities, to the decentralized system, making them nodes which can validate and add credentials to the DLT. In a second step, each accredited institution compiles all information that an education credentials contains – qualification or title, name of the certifier, name of the student, and issue date – into a dataset. This dataset is then digitally signed by the university and written into the ledger, thus making the validity of the credential immutable and publicly verifiable. Concurrently, uniquely signed digital certifications are given to the learners, for instance, in form of a PDF with a QR code linking back to the blockchain. The learners can now share these digital documents directly with their prospective employers who, in a third step, can automatically and from anywhere in the world verify the authenticity of the academic achievement. By scanning the QR code and comparing it with the hash stored on the distributed ledger, the hiring entity can instantly ensure that the credential is genuine. Therefore, DLT makes it possible to verify at any given time and place by whom and to whom a certificate was issued to, while validating the content of the credential itself.

In a more complex scenario, this idea could be expanded into a tool for modelling an entire web of trust and recognition of credentials that aligns with international streamlining efforts such as the Bologna process of the European Union. The web of trust would include information such as which universities recognise each other's credentials, which Ministries of Education, employers or independent and international bodies associate what level of trust and quality to which institution and to which particular degree or course. This would eventually blur the line between formal and non-formal educational credentials such as those taught on platforms like Coursera and Udemy. We can imagine our future LinkedIn profile to automatically cross-check and validate the provided credentials towards prospective employers. Such an integration of courses functions much better if the credentials in questions are issued and verified in a single standardised data format on a universal educational ledger, as opposed to thousands of institutions developing their own online verification mechanisms.

The added value of the solution

When examining the benefits of a blockchain solution over incumbent systems for archiving, sharing and validating education credentials, several benefits can be identified: first, the distributed nature of blockchain allows for major improvements in the transparent record keeping of certificates. At any given time, credential holders, the university or an employer who has been given access can audit the certificates by looking them up on the ledger. The immutability of records stored on DLT therefore makes various fraud scenarios harder to occur and easier to detect.

Second, once credentials are recorded on a public ledger, they become available for validation without the involvement of the issuing institution. This means that there is a standardised path to access credentials from any educational institution, no undue fees will be charged for validation services, and records can last beyond the lifetime of the institutions having provided the credential.

Third, thanks to the distributed nature of the network, education credentials become resilient to loss, cyber-attacks and catastrophic events disrupting physical infrastructure. Traditionally, certificates stored centrally either by the accrediting authorities or the individuals themselves are vulnerable to loss. In a blockchained system, even 99% of the nodes can fail or be disabled without the risk of losing the education claims that the system encompasses. There is no single-point of failure. Consequently, even if an accrediting authority should be closed down or destroyed – this has been the case for many universities in war-torn countries like Syria – the education credentials remain verifiable and valid. Accordingly, the more participating nodes a decentralised education credential platform encompasses, the more secure it will be.

Challenges and limitations

While a blockchain solution can ease portability and management of credentials, it does not automatically ensure the quality of the underlying education itself. Not all fraud scenarios can be ruled out, such as ghostwriting and some forms of corruption and identity fraud. The authenticity of the issued credentials still relies on certifiers and other trusted bodies vetting the trustworthiness of these institutions. Building such a comprehensive web of trust between institutions requires significant efforts that still need to be quantified.

Privacy is another major concern, as educational credentials contain personal data which not everyone would like to see openly available on the Internet. One approach is to use hashes; instead of publicising all personal details, you would merely store a digital fingerprint of the certificate on a public ledger that allows you to validate your otherwise privately managed credential details.

Furthermore, there can be limitations in terms of scalability. Today, the most prominent public blockchains are able to handle between three and 20 transactions per second. The chosen architecture needs to accommodate the needed performance to issue potentially millions of credentials on a single day during high school graduation season. While being technically feasible, e.g. as a hybrid blockchain, this currently requires compromises in the degree of decentralisation and security.

Beyond that, the added value of a standardised technical platform for credentials is greatest where the underlying educational framework also enjoys a level of standardisation, such as, for instance, the ECTS accounting that evolved in Europe's Bologna process of standardisation in higher education. Thus, educational standardisation, data standards and introduction of blockchain solutions should be well aligned.

Ideal application context

The stakeholder landscape of a blockchain-based platform for education credentials ideally includes (i) a trusted certifier, (ii) issuing institutions, (iii) learners, and (iv) prospective employing entities which want to verify the validity of the certificates in question. In terms of concrete application contexts for which such a solution would create benefits, we would look for a context in which credential fraud is prevalent and therefore trust in education is limited, while the labour market fails to recruit graduate students. In such circumstances, reliable education data could improve trust from employers, limit administrative burdens and truly reward merit among students who have obtained certified diplomas. Fraud patterns are easier to detect and flag as fraudulent if underlying data is made available for third party scrutiny. Additional benefits can be expected in contexts where educational institutions provide validation of credentials only against high fees and based on cumbersome and lengthy processes.

Current initiatives

Several universities and research institutions are piloting education credential programmes where students have their certificates available on an app built on DLT. The most mature solutions are currently being put forward by the MIT Media Lab in collaboration with the start-up Learning Machine and Fraunhofer FIT's Blockchain Lab. Both solutions focus on secure access and management of digital certificates. The platforms enable learners to credibly present their credentials and allow recipients to validate the authenticity of the documents presented. The Fraunhofer solution 'Blockchain for Education' offers the feature of 'deduced qualifications', i.e., the bundling of consecutive credentials into one cohesive qualification which are linked to Ethereum. MIT's digital certificate project similarly builds an ecosystem for registration of certificates on the Bitcoin blockchain.

- Fraunhofer FIT Blockchain Lab
- MIT Media Lab and Learning Machine

(ii) Distributed land registries

The challenge

70% of the world's population has no access to formal land registration systems. Globally, only 30 states have a functioning, countrywide land administration that also recognises local tenure systems.[7] In particular women, the poor and marginalised groups as well as indigenous people are the most vulnerable to arbitrary practices in land governance. Land tenure is a legal or customary regime which determines who can use land, for how long, and under what conditions. Land tenure security can be based on legitimate individual, household, family or community claims. The security of tenure is essential for economic development as it incentivises landholders to invest in their land, thus generating broader social and economic development.

Today, when a purchaser seeks to buy property, he or she must identify and secure the land title or any accepted document, such as existing deeds of sale, and have the lawful owner sign it over. For a large number of residential titleholders in developing countries, flawed paperwork, forged signatures and defects in foreclosure and mortgage documents have marred proper documentation of property ownership. The resulting situation is that the property has no 'good title' attached to it, being no longer legally sellable and leaving the prospective buyer in many cases with no solutions.

In addition, many countries struggle to properly register land tenure in the first place. In Africa, for instance, only 10% of surface area is formally documented.[8] Here, the gap between rural and urban areas is particularly noteworthy: while many large cities at least partly record land ownership, rural areas often lack any registration system. This is due to the fact that formalising and documenting the access to land is highly political and can be a costly and lengthy undertaking. In places where land tenure is documented, the registries most commonly rely on paper-based documentation, which is usually centrally stored, making it vulnerable to loss, corruption, or misuse. Moreover, natural disasters can affect such single-location paper registries. In the case of Haiti, for instance, large amounts of documents were destroyed during the 2010 earthquake.[9] The loss or manipulation of land documents creates social conflict and negatively affects the trust in governmental services. Paper-based land registries are likewise plagued by significant inefficiencies. Land transfer processes often require a variety of hard copy documents and third-party verification as well as stamp duties. These costly, complex and time-consuming procedures take liquidity out of the land market, obstruct investments and hinder economically efficient allocation of land tenure documents.

Land registries on a blockchain

From a bird's eye perspective, DLT captures and permanently stores a hash of each transaction of land, which allows close to real-time traceability of

ownership changes, as well as transparency on the state of the property without the possibility of manipulation of existing titles. More concretely, imagine two citizens who have agreed on the sale of a land parcel and now wish to register the sales contract with their country's land administration. Similarly to the registration process with a traditional land registry, the seller and the buyer go to the governmental administrator with the sales contract signed by both parties and enter it into the blockchain-powered land registry database. Hence, the public ledger will be provided with a privacy-shielded set of data, i.e. the fingerprint or hash of the full transaction – the latter being stored privately. Once the transaction is approved by the network and added to the ledger, the transfer of ownership is immutably recorded and the blockchain becomes a single point of truth, preventing document forgery and corrupt land transfers. If there are doubts as to the validity of a land ownership claim, the public ledger can be consulted for validation by all stakeholders involved. Similarly to the education credential scenario, a smartphone app or web platform could be used as a user interface to that end.

In a more advanced and disruptive scheme, the property transfer itself is no longer conducted within the traditional governmental mandate, but rather in the form of a smart contract directly between involved parties.

This implies the complete digitisation and to legally formalise the peer-to-peer sale and purchase of properties, thereby cutting out the role of intermediaries such as banks, notaries and public registry offices. Taken to the extreme, this would mean that a smart contract on a public ledger, digitally signed by the parties, would inherit legal authority by automatically transferring the land title upon payment in the form of cryptocurrency. This scenario, however, comes with a number of prerequisites and caveats of which some are unlikely to be met in the near future. The digital frontrunner country of Estonia has moved almost all government transactions online, except for the procedures of getting married and transferring property. Given that these kinds of transaction require physical presence due to their sensitivity, solely relying on digital signatures appears to be insufficient. Therefore, trusted middlemen performing checks on identities and signatures are likely to remain in place for the time being, making it unlikely that a million-dollar land transaction will be completely decentralised. Likewise, governments will most likely continue to act as a verifier of legal preconditions for the transfer of property, as the public ledger would rarely include data on whether the owner is adult and mentally sane, and otherwise legally able to sell a given piece of land. Accordingly, we expect smart contract-based land titles to become legally binding only once these checks and safeguards of trusted middlemen are reliably provided in the form of digitally signed oracles. Oracles are third-party information sources that provide external data of verified real-world occurrences to the blockchain and trigger smart contract executions. In the context of land administration these oracles would digitally represent the preconditions for land transactions to be executed via smart contracts.

The added value of the solution

Much of the efficiency gains of the blockchain-based land registry can be attributed to processes having digital workflows as opposed to being paper-based. Digital workflows in a land registry can save time, be remotely accessible, avoid certain corruption scenarios, and improve data quality and reliability of storage. Also, a decentralised land registry promises to create great efficiency gains in administration-related governmental mandates such as land taxation. Here, DLT adds value through its immutability and resilience. The fraud and corruption scenarios that rely on the forging or 'disappearing' of documents, or attempts to sell land twice, are effectively discouraged by a timestamped hash on a public ledger. This would especially benefit marginalised groups in society, such as women or indigenous populations, who are often the victims of land fraud. In addition, while existing backup technologies can provide a good level of reliability for data storage, the reliability of distributed ledgers, with sometimes several thousand copies worldwide, is unprecedented, and works even in the absence of qualified (or in the presence of corruptible) IT personnel on site.

The more disruptive scenario of smart contract-based land transfers provides an occasion and opportunity for a more fundamental reform of institutions and their mandates. Each intermediary along the process is stripped to its core functionality, such as, for instance, verifying identities and signatures. This institutional restructuring based on clear definition of roles – for each function a corresponding oracle – can break up existing inefficiencies, corrupt structures and collusion.

Generally speaking, the increased transparency brought by blockchain-based land registries can therefore contribute to boosting citizens' and companies' trust in public institutions. This, in turn, may translate into growing investments and use of land, spurring social and economic development at a larger scale.

Challenges and limitations

Despite the various advantages of DLT for land registration, a number of challenges still have to be taken into account. The comparably simple solution, i.e. timestamping transactions of existing land registries by writing hashes on a public ledger, is relatively straightforward and easy to implement. Yet, in which land transactions are executed in a fully automated manner through the use of smart contracts comes with several ramifications. First, land titles and obligations are often complex and involve additional information beyond the identity of the land tenant. For instance, mechanisms and procedures have to be defined for land seizure in cases of insolvency etc. Projecting such complex systems of rules and obligations into a blockchain will not only require careful and thorough coding of smart contracts, but will also require institutions to go through significant adaptations in their management processes.

Second, the legal status of smart contracts needs to be specified, possibly requiring legal amendments of contract law, along with the changing role of the institution of the land registry. In addition, there might be questions regarding data sovereignty. Privacy and data-hosting laws vary by state, and some are more strict than others. Some of these challenges may be addressed using privacy enhancing technologies such as zero-knowledge proofs. Simply put, zero-knowledge proofs allow person X to prove something to person Y without having to transmit any information about the thing itself.

A third hurdle relates to the lack of maturity of blockchain technology. Public blockchains are a phenomenon of the past 10 years, while land titles are meant to be kept for up to 100 years or more. Therefore, we need to assess risks and shortcomings of blockchain architectures. Data may need to be migrated at some point if the chosen architecture seems no longer suitable. Energy consumption and scalability questions of current blockchain systems add to these technological concerns. It will be fundamental to choose a blockchain platform which can accommodate the need for millions of land registry entries. Lastly, digital infrastructure and literacy are important preconditions. The responsible governmental bodies have to be Internet connected and digitally adept to maintain and manage the decentralised registry.

Overall, blockchain is unlikely to render trusted middlemen obsolete in the near future. Nonetheless, it can create more accountability by creating an immutable audit trail and handing over more control over land transactions to citizens. This makes it possible to fend off certain corruption or loss of documentation scenarios. Furthermore, while it may not resolve questions regarding the costs and problems arising from land regularisation and land ownership determination – two important processes for the generation of quality data – the technology can ensure that the time and effort invested in these processes will not be undermined by fraudulent actors at a later stage.

Lastly, it may be worth mentioning that, so far, it remains unexplored whether it is viable to integrate blockchain-based land ownership into traditional or non-western land governance systems.

Ideal application context

Blockchain-based recording of land titles is particularly relevant in contexts where existing land licensing and registration processes are facing fraudulent and corrupt practices, particularly related to document fraud, double selling, or risk of malicious actors linked to governmental institutions confiscating land. The auditability and transparency introduced by a DLT would significantly increase trust in the land registry and management. Furthermore, if a digitised cadaster or registry already exists, the investment to write checksums onto a public ledger is relatively small.

In terms of the more sophisticated scenario of a smart contract-based land registry, the complexity of the legal context can be a challenge for implementation. A comparably simple regulatory environment and a reduction in project scope (not covering all exceptions) is advisable. Another enabling factor is the existence of a competitive private sector which pushes for reform in land registries, seeking to benefit from cost-efficiencies. While the technology presently appears mature enough for the simple use case of timestamping land transactions, the more complex use case of smart contract-based land titles should preferably first be implemented in the form of a regionally restricted pilot project, with possible extension of scope upon success.

Current initiatives

To date, there are several pilot projects for blockchain in land registration. The most successful pilot was, arguably, implemented in Georgia by the National Land Administration and start-up Bitfury with institutional support of GIZ. As mentioned in the introduction of this publication, the land titles are recorded on the Bitcoin blockchain. Keys to success were the already prevalent digitised land documents as well as the political will and feasibility of adopting the regulatory environment. In another promising pilot project in Sweden, a heavily regulated legal environment currently still poses significant hurdles for broader adoption. Pilot projects in Honduras, Ghana and Rwanda have had limited success so far. While some initiatives are driven by the private sector without legal recognition and state-backing, others are struggling with the above mentioned difficulties of land registration.

(iii) Decentralised energy markets

The challenge

Universal access to energy is crucial to almost every major challenge and opportunity the world faces today – health, education, food security, employment and climate change, to name a few. Therefore it is explicitly recognised as a key enabler for development in the Sustainable Development Goals, namely in SDG 7, 'Affordable and Clean Energy'. Technological advancements will play a decisive role in achieving the Global Goals, e.g. improve energy efficiency, promote renewable electricity generation, and increase access to modern energy services.

The necessity for action becomes obvious when looking at some global key figures regarding energy: currently, around 14% of the world's population have no access to electricity – more than 50% in Sub-Saharan Africa alone – and about three billion people still rely on polluting combustibles such as wood and coal for heating and cooking.[10]

The current energy systems have a long lasting legacy to overcome. For decades, fossil fuels such as coal, oil or gas have been major sources of electricity generation. They resulted in highly centralised energy systems focused on large generation plants using high-voltage power grids to distribute electricity. While legacy grid infrastructure remains highly centralised today in many economies, two mutually reinforcing trends are pushing towards decentralisation: increasing use of renewable energy and digitalisation. With increasing variable generation from sources such as wind and solar power feeding into the grid, new needs for flexibilisation are in demand, e.g. improved battery storage, predictive analytics, smarter grids or demand side management. Planning, connecting or hooking up new electricity generators to existing grids becomes more complex. This is where digital technologies such as blockchains, data analytics or artificial intelligence might play a key role.

In countries with low levels of electricity access, both on-grid (traditional power lines) and off-grid solutions (mini and micro grids) are crucial for achieving universal access. This development is supported by decreasing costs for renewable energy technologies such as photovoltaic (PV), and a focus on energy efficiency measures that can help countries extend access to energy for their populations. However, all measures need to be backed by an enabling environment with the right policies, regulations, and financial incentives.

When talking about blockchain and energy, we have to note that most projects are currently at an early stage with limited maturity. Although many blockchain applications may add different values to electricity systems, there are few projects that serve as proof thereof. In the context of development cooperation it is therefore vital to understand that the only way to show the actual added value of the technology is through implementing small-scale pilots and analysing their added true value.

In the next paragraphs, we will focus on the potential the technology has in creating new markets for electricity trading: peer-to-peer (off-grid microgrids or with distribution grid access) as well as wholesale trading (grid access). The selection is based on two findings. On the one hand, there are the first pilots being conducted in this area. On the other hand, the value chain 'retail in the energy sector' tends to offer the simplest conditions for implementation with, at the same time, presumably high added value in the development context. Current examples include wholesale markets between generators and retailers such as the German Enerchain consortium with its 50 European utility members, or between individual households such as in the Sukhumvit neighborhood in Bangkok or the Brooklyn Microgrid in New York. Even in areas that remain disconnected from distribution grids, neighbours with solar rooftop PV systems, improvised grids and smart meters can start trading with each other on a peer-to-peer basis, as demonstrated by the start-up Solshare in Bangladesh.

Electricity markets on blockchains

A well-functioning energy system is dependent on data being shared correctly, quickly and uniquely with the relevant actors within the system. Therefore it is crucial how large data streams from decentralised feed-in, smart metering or grid operation can be managed. Blockchains promise a more efficient and resilient IT-infrastructure in comparison to existing systems to manage aforementioned data in distributed electricity systems, while allowing for a new level of transparency, tamper resistance and security.

The above advantages of blockchains may open up considerable potential in electricity trading. As mentioned, we think in terms of two models. One model would make it possible to enable exchanges for wholesale electricity trading on a blockchain basis. This can be interesting, for example, in contexts where cross-border electricity trading is to take place and one wants to trust the technology rather than a state authority – if existing – to record and pay for the quantities of electricity. The other model is based on the assumption of a microgrid. In this off-grid system, the blockchain should allow energy trading between participants connected within the microgrid.

Blockchains can function as a shared information and transaction platform for all market participants. Electricity generation and real-time demand are recorded on the blockchain by using Internet-enabled smart meters, while the transactions between the participants are executed and documented automatically on the blockchain. Blockchain's ability to make even the smallest data transactions economically viable ultimately entails new degrees of participation and incentives.

Electricity marketplaces are heavily dependent on data integrity. Therefore, one part of the solution needs to collect data streams from decentralised electricity feed-in. Validity of this data is best ensured by using tamper-proof cryptography-enabled hardware as well as an algorithm cross-checking various data sources against each other. Based on such validated data sources, a blockchain-based electricity marketplace cannot only unite the demand and supply side for energy purchases, but also immediately settle the transactions, including monitoring the delivery of electricity and processing of corresponding payments. Smart contracts can ensure that electricity is requested, for example, when prices fall below a price threshold or when green electricity or local power is available.

In general, in order for electricity markets to work efficiently, they should have a low entry barrier, be accountable, transparent, and have low transaction costs. Current mostly centralised electricity marketplaces often have high entry barriers due to, for instance, thequantity of power to be traded, a lengthy registration process and technical accessibility. As a result, overall operational transaction costs for electricity retailers are high, even if the actual transaction fees might be low. As a neutral and comparably cheap IT backbone, DLT helpscreating a marketplace with an increased number of participants.

The added value of the solution

DLT solutions have several advantages compared to traditional electricity marketplaces. As described above, they might lower market entry barriers for participants, thus allowing and incentivising new actors to partake in electricity trading. Blockchain-assisted trading could create new incentives to invest in and operate renewable electricity generation by providing a highly automated and yet secure way to buy and sell electricity. Blockchain technology promises direct, anonymous trading of various electricity products (e.g. day-ahead, spot market) without the need to involve a 'physical' electricity exchange or intermediary as it enables trustworthy transactions between players who do not know or trust each other. Furthermore, such trading systems might lower the need for ancillary services since price signals can be implemented that secure the stability of the grid. Thereby, particularly in countries that do not yet have energy trading systems or exchanges, completely new markets could be created and far-reaching investments could be achieved. The consequences for the consumer would be greater security of supply, but also the possibility of incentivising own renewable electricity generation and directly benefiting from their investments.

In this context, we have to note that most projects are currently at an early stage with limited maturity. Although many blockchain applications may add different values to electricity systems, there are few projects that serve as proof thereof. In the context of development cooperation it is therefore vital to understand that the only way to show the actual added value of the technology is through implementing and evaluating small-scale pilots.

Challenges and limitations

The prerequisite for blockchain-based marketplaces is that the participating electricity generators are equipped with smart meters that communicate via the Internet. They provide accurate data on the quantity and price of the power to be traded. The information about these specifications is secured on a blockchain. Therefore, marketplace models cannot be implemented without digital hardware that bears the corresponding costs.

Although the prices for renewable energy are decreasing and become competitive, or even cheaper than fossil fuels in some countries, the centralising legacy of the latter remains. As mentioned above, the majority of electricity systems globally are still based on fossil fuels today. The switch to renewable energies and the associated costs, which will lead to more fragmented competition for electricity trading and allow for marketplaces involving several actors from the start, is therefore an essential factor.

Even if renewable energy generation is to be found in a country and its level of digitisation is sufficient, especially smart meter penetration, state and regulatory authorities remain of enormous importance. Energy systems are often heavily regulated by the state or, in some cases, controlled by a state-owned corporation. Therefore, electricity trading – be it in wholesale markets or on a peer-to-peer basis in microgrids – might not be covered by a legal framework and therefore not implemented.

Finally, the existing and planned grid infrastructure remains of high importance – even in off-grid microgrids. Investment costs in this infrastructure are generally high and even with the result of creating a new market, the return on investment might not be secure.

Ideal application context

An optimal implementation environment is first and foremost dependent on the regulatory landscape of the country at hand. Looking at energy trading on a distributed ledger, it will require a context with a sufficient degree of liberalisation that allows various actors to trade electricity in the first place. Wholesale markets tend to be more liberalised than retail markets – as regulators often shield private households from price signals.

Since high potentials are to be expected in both cases, also for the regulator, a regulatory adjustment cannot be ruled out. However, this would take a correspondingly long time. Regulatory sandboxes (i.e. 'live-like' testing environments set up by the regulator to allow innovators to test their products and business models without following some or all usually applicable legal requirements) would be an attractive alternative that would make it possible to test the cases. In these locally and temporarily restricted frameworks, suitable cases could be tested with blockchains.

On the technical level, reliable data sources need to be available. This is more often the case in network operations than at retail level. Pilot projects could start with rolling out blockchain-enabled smart meters which would likewise work in rural off-grid locations, with communication links established by wire or through Wifi or low-power wide-area networks (LPWAN).

Current initiatives

Projects worth looking at include:

- Energía Abierta – open energy-grid data platform in Chile
- ME SOLshare – peer to peer electricity trading in rural microgrids
- Brooklyn Microgrid – peer to peer trading of renewable energy in Brooklyn, New York

- Enerchain – Consortium blockchain for wholesale electricity and gas trading
- Energy Web Foundation – blockchain solutions for grid operations and certification of green electricity generation

(iv) Decentralised parametric insurance

The challenge

Insurance is a crucial risk transfer tool to make businesses and individuals more resilient to unfortunate events by enabling faster recovery and allowing them to hedge against a possible loss. While the industry's services have been steadily expanding, the insurance sector still faces several challenges: high administrative costs and inefficiencies due to the prevalence of paper-based information flows, manual claims reviews and processing and the fragmentation of data across suppliers, to name a few. Moreover, structural issues include moral hazard leading to faulty claims adjustment processes and information asymmetries on risk levels which lead to adverse selection, i.e., a situation in which a person's demand for insurance is positively correlated with the person's risk of loss. As a result, insurance systems may suffer from low trust and high transaction costs while being prone to fraud. Additionally, from a development perspective, emerging economies often struggle with insufficient or underdeveloped insurance frameworks which means that for many individuals, especially of the poorer and more vulnerable segments of the population, insurance products are unavailable or inaccessible. Insurance markets may have limited competition because of licensing requirements and economies of scale, leading to market concentration, and one or few large companies may be able to extract unjustified high rents at the expense of their clients.

Blockchain-based weather index insurance and its added value

An innovative way to address some of these challenges has been the introduction of index-based insurance. For this type of insurance external

data sources, such as weather stations or aerial imagery, produce data for indices which in turn underpin the insurance contracts. Consequently, the index values can 'trigger' payments to the insured party automatically, without the need for any claims adjustment or other human intervention.

As payments are triggered in response to predetermined events, index-based insurance products can be transacted through, and eventually replaced by, smart contracts. Once a trustworthy system in the form of an oracle (a data feed that provides information of verified real-world occurrences to the blockchain and triggers smart contract execution) has been created to upload information to the DLT, smart contracts facilitate payouts in the event of a predefined condition being recorded. In the case of weather index insurance this could be droughts, cyclones, excessive rainfall or an earthquake of a certain magnitude. Through such a mechanism, problems associated with dispute resolution can be easily resolved with reference to the decentrally recorded authentic sensor data whose validity is technically ensured and has been accepted by all participating parties beforehand. As a result, index-based weather insurance becomes more accessible and affordable to individuals, while increasing the resilience of vulnerable households and enterprises.

Beyond that, insurance companies can offer hybrid tailored products to their customers that rely not only on publicly available climate data, but also monitor smallholders' cultivation practices through crop and soil sensors, e.g. measuring soil moisture with sensors and the irrigation amount through smart water management devices. By overseeing smallholders' management practices and ensuring their quality, premiums can be reduced and thus make insurance services more accessible. Furthermore, other stakeholders in the value chain can be involved in the system to facilitate the exchange of information between insurers, finance providers, agricultural input manufacturers and smallholders. Such a transparent information sharing system would not only improve trust between all parties but also lead to a decrease in costs as data verification would not have to be conducted several times.

In other words, smart contracts can help facilitate many of the intricate insurance processes even for traditional insurance products, by automating procedures such as claim validation or payments and at the same time leveraging the true added value of decentralisation in multi-stakeholder environments where trust is missing, especially in exchanging data. Moreover, once suitable oracle data for index-based insurance is made available, the insurance policy's smart contract can easily become a globally traded commodity, with subsequently more competition and drops in price. The latter would converge towards the statistically expected value of predictions of the climate index in question. This vertical disintegration of the insurance market into separate oracle provision, climate risk predictions, and marketing would be the enabler for a highly liquid and competitive market.

Challenges and limitations

Despite the advantages and the disruptive potential of blockchain-based weather index insurance, some risks still need to be addressed. Deploying smart weather contracts would have to be carefully aligned with the regulatory and supervisory system governing solvency and consumer protection in the country of implementation. From a legal standpoint and as the downside to the trustworthiness created by the sharing of user data, data protection and privacy concerns have to be taken into account. Similarly, the 'transparent user' can become a significant barrier for individuals who wish to access services but whose profile might disqualify them. In addition, there is a set of risks associated to using cryptocurrencies that need suitable mitigation. The risk of loss or disclosure of cryptographic keys can be mitigated using trusted key management services. The high levels of volatility of cryptocurrencies can be mitigated by using less-volatile alternatives, such as a crypto-asset pegged to the local currency or to an international reserve currency.

There are limitations to the scope of risks that can be covered using parametric insurance policies – regardless of whether the insurance is traded in the form of smart contracts or not. While climate events can be tracked as an index, individual behavior such as smallholder farming practices can hardly be tracked in an index. Similarly, the challenge of marketing insurance policies to farmers remains in place. Even if blockchain-based policies prove to be cheaper, this may not be enough to convince farmers of the benefits of buying insurance in the first place.

Ideal context of application

The implementation of a simple weather index insurance based on a smart contract and accessible via a mobile apprequires access to relevant weather data and customers with smartphones and Internet connection. More concretely, an optimal setting for a pilot using smart weather contracts would be an existing farming scheme, e.g. contract farming, with a sensor system and supply chains already in place.

Current initiatives

One of the most prominent decentralised insurance initiatives is currently driven by Aon, Etherisc and Oxfam and seeks to give Sri Lankan smallholder farmers access to blockchain-enabled micro-insurance. A related project is the 'Sprout Climate Insurance' lead by Etherisc which aims to make insurance fair and accessible beyond the pilot in Sri Lanka. Sprout is a one-click insurance for farming where payments are triggered based on weather data from satellites, sensors or weather stations. An already existing and functioning insurance market solution is Fizzy, an Ethereum-based insurance platform for delayed flights. In this case the automated, rather than decentralised nature of blockchain is being utilised to trigger instantaneous payment to customers facing flight delays. The Silicon Valley based startup Climate Corporation offers parametric climate insurance using data analytics, currently without blockchain.

- Sri Lanka Project
- Sprout Climate Insurance
- Fizzy
- Etherisc

(v) Tokenised social impact marketplaces

Problem description

How can one best align entrepreneurial creativity with governmental objectives? This question has been preoccupying policymakers and development practitioners for decades. One of the answers has been social impact bonds, for instance, which leverage additional forms of capital from investors and the know-how of social ventures to achieve a predefined societal goal in education, health or employment for example. By engaging external actors, this type of contract helps reduce a government's potential risks in both financing and execution, enhancing the efficiency of public spending and supporting more transparent and market-oriented project delivery. However, they typically rely on complex mechanisms that require various parties to be coordinated, incentivised and held accountable through contractual terms.. Additionally, the process of gathering outcome data is sometimes prone to actors gaming the system, while the calculation and allocation of payouts to the actors creating the impact is far from straightforward. Meanwhile, other cost-efficient alternatives focusing on social impact have remained limited. Today, governments and the development community in particular still struggle to find better ways to incentivise and fund impact.

Tokenising social impact

Instead of setting up a paper-based contract, tokenisation relies on a digital representation of impact, namely an impact token. This means that those actors who deliver impact generate 'claim of impact' crypto-tokens whose validity is checked by a third party validator. Once the impact is validated, a smart contract is triggered enabling the value of the token to be redeemed. Such a process can be widely automated: for instance, upon generating electricity from a rooftop solar cell, one impact token can be generated for each kilowatt hour, with automated validation built into the power inverter module. Another example is aerial imagery and land registry data which can be used to verify impact tokens corresponding to the degree of reforestation conducted on a parcel of land. Or water quality sensors can issue tokens to reward upstream farmers for reducing fertiliser contamination.

Beyond automation, this tokenised scheme allows impact to be traded on a many-to-many marketplace platform. The demand side of this marketplace, i.e. those who are willing to spend money in order to achieve a certain impact, may consist of governments, philanthropists and corporate players alike. The supply side, i.e. those who deliver impact in return for financial reward, can be a diverse set of stakeholders as well, including NGOs, social ventures, companies, governmental entities, and even individuals. Supply and demand determines the market price for each type of impact measured, while the marketplace ensures effective allocation of resources, i.e. that tokenised incentives are directed towards those actors and projects which are able to drive impact in the most cost-effective manner. The demand side will moreover define the mechanism of validation that is required for tokens to become redeemable.

One of the key requirements for such a scheme to gain traction is the reliable verification and attribution of impact. In an idealised scenario, verification would be fully automated using trustworthy data sources such as aerial imagery and sensor networks, so-called oracles acting as third party validators which provide data of verified real-life events to the blockchain and thus automatically triggering token rewards via smart contract. Such a system would bypass the risk of human error and leave less room for corruption. In practice, however, the scope for full automation of impact rewards still appears very narrow nowadays, which means that we may often need to partly rely on centralised trusted entities for verification of impact. For example when it comes to measuring job creation, reliable verification depends on manually checking paper based work contracts as long as work contracts are not concluded online.

Furthermore the distributed impact market mechanism adds value by lowering the entry barrier for impact service providers and thus increasing competition which, in turn, may reduce the cost per unit of desirable impact. Implemented on a public ledger on the Internet, impact incentives may furthermore be able to scale quickly at global level. A factor which could potentially be used to enable impact creation in areas hard to reach through traditional development projects, such as North Korea or the favelas of Brazil. As a future perspective, these tokenised claims may be integrated to govern economic value chains, for instance, we can imagine producers of plastic products being held accountable through an obligation to purchase impact tokens against plastic waste for each ton of plastic products sold.

The added value of the solution

The benefit of relying on a decentralised solution covers different aspects. First, there is cost reduction. Standardisation and automation in impact verification and payment processes promise significant efficiency gains. Furthermore, investments in impact would become more scalable and accessible to wider segments of possible investors – private individuals can invest a few dollars whereas larger entities can invest millions. Within the development sector, such a tokenisation of outcomes would create liquidity for projects that are otherwise difficult to finance. Small and hard-to-reach projects in particular might find it easier to create tokenised impact claims and thereby signal impact generation to potential investors. Moreover, the newly created token economy offers new well-targeted policy tools to internalise harmful externalities of economic value chains, such as climate impact or environmental and health risks. Plus, such models could be deployed quickly at scale, meaning they can also be relied upon to effectively raise private capital in times of emergency. Finally, and depending on the openness of DLT implementation, projects can also be compared with each other and draw valuable data insights from each other.

Challenges and limitations

One major challenge for social impact marketplaces is the need for accurate and hard to manipulate impact data which rules out many potential projects whose impact measurement methods would be too easy to game; and even for those that can be measured reliably, the costs for setting up the needed oracles might be inefficiently high. Beyond that, the impact attribution questions must not be neglected. Causal impact attribution (how do we know that outcome X is a result of input Y) is a problem that has plagued impact work from its beginnings and will hardly be solved by a blockchain-based solution. For example, we often cannot distinguish whether good school performance is attributable to the delivery of quality education, or whether it is a result of selecting the brightest talent as pupils. Furthermore, by creating a globally accessible market for impact, an entirely new dimension of challenges regarding safeguards and do-no-harm aspects will arise. Local knowledge needs to be included in a smart mechanism for curation of projects and validation of impact – otherwise we risk creating misguided or even harmful incentives hindering sustainable development in the long-run. Last but not least, compared to traditional SIB, the described solution is covering merely impact incentives and may often require a suitable additional investment vehicle to mobilize capital on the supply side.

Ideal application context

For social impact marketplaces to work well, important preconditions are the measurability and attribution of impact, ideally automation (through automated monitoring data sources), and suitable safeguards for 'do-no-harm'. On the one hand, to derive the full added value of tokenisation, development outcomes need to be clearly defined upfront. Impact indicators can, for example, be school attendance or educational attainment. To guarantee that the information entering the blockchain is accurate and the corresponding impact token is representative of project success, trusted oracles are needed. On the other hand, the stakeholder landscape involved in the tokenisation needs attention too. To guarantee local ownership and sustainability of the project, user-centered design and the inclusion of all the concerned actors is fundamental

Current initiatives

There are a few tokenising impact initiatives in the blockchain space, the ixo Foundation being the most prominent one. In South Africa, the Amply project supported by UNICEF and Innovation Edge was recently launched, using ixo's protocol for a mobile app to monitor attendance in pre-schools in South Africa. By digitising the process of school attendance verification and putting the information on a blockchain, a proof of impact was created for investors. The major challenges were creating a sound identification system for girls attending school in order to prevent overreporting. In other words, measurability and accurate data are keys to success of tokenised social impact marketplaces.

- Amply
- ixo

CHAPTER 4

Blockchain in international development: a practitioner's guide

Under which circumstances should I consider DLT?

Having examined several promising blockchain use cases within the realm of the 2030 Agenda, we can start exploring under which circumstances using DLT can benefit specific development projects. Assessing whether you should consider deploying DLT for the advancement of your development objective depends on seven factors:

(i) the characteristics of your development challenge

(ii) the need for and reliance on a database to solve it

(iii) the merits of decentralisation for your objective

(iv) the technical feasibility of your envisaged blockchain solution

(v) the legal environment in which your project is embedded

(vi) the political and institutional landscape

(vii) the existence of other technological alternatives.

Given the very different types of DLT, their interlinkages with other technologies, and their wide spectrum of application, a comprehensive answer will additionally require further individual assessment. No one-size-fits all approach exists when it comes to determining if and under which conditions blockchain could be used. The following scheme will however offer you some initial guidance on how to structure your decision-making process when answering the fundamental question: 'Should I consider blockchain for tackling my development challenge?'

Checklist of questions to ask

The blockchain hype, confusion about what the technology really is, and sometimes flamboyant marketing claims of technologists have made it difficult for decision-makers in development cooperation to decide whether or not it is advisable to rely on DLT. In fact, the media's constant swing back and forth between adulation and disillusionment regarding blockchain and cryptocurrencies has clouded perceptions of what a successful application of blockchain really implies. This is not to say that deciding if, when and how to deploy DLT is an easy task to accomplish. The technology is still largely in its infancy, which makes it hard to pin down definite success factors. A useful starting point to find some answers to these questions can be to look beyond the technology itself. So let's start focusing on some core considerations you will have to address when thinking about using DLT for your development challenge:

(i) What is the problem you want to solve?

Always start with the problem. Blockchain has often, and not entirely without reason, been called a solution looking for a problem. It is therefore essential that you aim to solve a concrete problem within your development context rather than putting great efforts into designing a challenge that the technology can solve. A common pitfall is to build a project based on what you like and what is hyped and then try to convince everyone else that this is the way to go.

(ii) Do you need a database?

The second basic question you have to ask yourself is whether your project is in need of a database which captures digital assets, i.e. anything that can be stored, tracked and validated electronically. Because after all, at its very core, blockchain is a database, a system for keeping records. Should your answer to the above question be 'yes', you can jump right into the next assessment framework segment.

(iii) Is there added value from decentralisation?

While blockchain is a database as mentioned above, it is not yet a usual one. A DLT solution will require from you to share a ledger system with other, at times unknown, parties. It allows every network participant to verify and validate changes to the ledger or add permanent data. The decentralisation of the database therefore makes it more transparent, secure to manipulation and trustworthy. Accordingly, as a rule of thumb you can say that if a central database is less effective than a decentralised solution, you might want to consider DLT. In other words, should there be no appropriate reasons for deriving benefits from decentralisation, a normal database will do the job. You can determine the added value of decentralisation for your envisaged area of application by asking yourself: is there a lack of trust among the key parties involved?

Namely:

- Are there any conflicts of interest?
- Does the high number of users impede on trusted cooperation?
- Can parties gain at the cost of other users by cheating, compromising data etc.?

Is foregoing the existing central authority beneficial?

Namely:

- Are there monetary or time efficiency gains to be achieved by bypassing existing intermediaries?
- Are existing central authorities potentially corrupt and/or dysfunctional?
- Do existing central parties extract monopoly rents?

If your answer regarding the reliance on a shared database is 'yes', using DLT for your project might be an option as the technology's inherent added value, namely decentralisation, seems to be adequately leveraged. Nevertheless, this preliminary assessment does not give you absolute certainty that your chosen area of application also matches the technical requirements for a DLT use case. We therefore need to pursue with the question:

(iv) Is a DLT solution technically feasible?

Given that DLT enables the transfer of digital assets, there is a relatively high incentive for stakeholders to game the system, i.e., manipulate the data before it enters the shared ledger and becomes immutable. A circumstance more commonly known as the 'garbage in, garbage out' problem, which means that no blockchain can compensate for a lack of accurate, timely and authoritative data at the point of input. Bad data cannot be made good. By technical feasibility we therefore imply the construction of an information system in which you can rely on all data entry points. This does not necessarily mean that you need to trust all participating actors (on the contrary, blockchain is touted as a trustless technology), but rather that you can trust the system to have adequate incentives or safeguards in place to ensure that the data entered on the blockchain is genuine. Hence, as a rule, you can say that you might want to consider DLT if you can ensure that the data captured by it is trustworthy. Or to look at it another way, you can determine the technical feasibility of using DLT in your envisaged area of application by asking yourself: can you trust all data sources used – software, hardware or human?

Namely:

- Do you rely on sensors or any other kind of accurate external data sources that are hard to manipulate ?
- Can the collection and transfer of data to the blockchain be delegated to trustworthy entities such as local institutions, reputable NGOs or agencies?

Is the nature of the solution such that transactions can be executed automatically, without the possibility of manipulation?

Namely:

- Are the changes in the database conducted electronically?
- Or are access, writing and administration rights to the database restricted to trustworthy actors?

Should you be able to respond positively to these two primary questions, the deployment of DLT for your envisaged development objective or project is a possible option. As a next step you will have to evaluate the regulatory setting in which your blockchain solution will be embedded.

(v) Is a DLT solution legally feasible?

While DLT solutions for development purposes might be workable on a technical level, in many cases you will not be able to implement them without first modifying the legal environment applicable to the issue at hand. Considering DLT's cross-jurisdictional nature – the nodes of a blockchain can be located anywhere in the world – the use of the technology gives rise to a number of complex regulatory questions in terms of applicable law, jurisdiction, liability and dispute resolution. At its simplest level, every transaction could fall under the jurisdiction of every node in the network. DLT also causes concern in view of data protection laws, especially where the relevant data is linked to an individual. The immutability of the data stored on the blockchain, which often goes hand-in-hand with its pseudonymity, triggers questions, for instance regarding the right to be forgotten or compliance with (sometimes competing) data localisation legislation.

Either way, innovative solutions that focus on making the legal system compatible with the realities of DLT are needed. As this is largely uncharted territory, you will make no progress without doing some creative and out-of-the-box thinking. In certain cases, you might have to engage the responsible legal authorities to adjust the regulation concerned or create entirely new laws. In other cases, it may prove more useful to adapt your solution to the legal context or design the DLT project in such a way as to bypass the legal hurdles. When the latter is impossible and legal barriers prove to be insurmountable, it is preferable to discover this as early in the project process as possible. Addressing legal feasibility questions at the assessment stage ultimately enables you to use resources more efficiently over the long run and move your project beyond pilot. Hence, as a rule, we can say that if existing laws are not affected by a decentralised solution or that they can easily be adjusted, you might want to consider DLT. In other words, you can determine the legal feasibility of using blockchain in your envisaged area of application by asking yourself: do existing laws and regulations conflict with the envisaged DLT solution?

Namely:

- Are national laws opposed to a ledger controlled across state boundaries?
- Does the introduction of exclusive jurisdiction and governing law clauses to the DLT solution prove to be impossible?
- Does the immutable storage of data conflict with data protection laws?
- Is the applicable law prohibiting token economies?
- Does the smart contract (if there is one) fail to represent a legal situation?

Does a viable alternative to circumvent conflicting norms exist?

Namely:

- Are opposing regulations easily adaptable?
- Can regulatory sandboxes be created, i.e. real-life testing environments set up by the regulator so that innovators can test their products and business models without the need to follow applicable legal requirements?

On a general note, given that permissioned DLT or regulated permissionless DLT run by certain rules, they can be more easily regulated and forced into current regulatory frameworks. This does not however mean that applications built upon public blockchains cannot be legally implemented. They might just come to be more dependent on legislative adjustments or legal sandboxes. If you have answered the first question above with a 'no', the second question with a 'yes', you can move on to the next segment. As a sixth step of the assessment framework, you will have to take a look at the political implications caused by the deployment of the blockchain solution you envisioned.

(vi) Is a DLT solution politically feasible?

As a disruptive technology, DLT sometimes 'competes' with existing governance structures. As Michael Graglia and Christopher Mellon accurately note, "blockchain is unusual in that it is a social technology, designed to govern the behaviour of groups and people [...] it is therefore inherently political."[11] Its likelihood of success may therefore depend upon the willingness of central authorities to delegate control. This means that on the one hand, DLT projects can be stimulants that force these actors to view their role from other perspectives, obliging them to develop new governance patterns which do not rely on their role as trusted middlemen. On the other hand, giving up control and power never comes easily and rarely without a cost as incumbents tend to hold onto their privileges. So, as with so many digital breakthroughs, it is the disruptive nature in view of existing processes and business models that stands in the way of the broader adoption of blockchain applications. In consequence, as a rule of thumb, we can say that if your distributed ledger solution does provide an incentive for existing institutions to hand over control, you might want to consider using DLT. You can determine the political feasibility of using DLT in your envisaged area of application by asking yourself: is the legitimacy of existing institutions undermined by DLT?

Namely:

- Does the blockchain solution allow existing central actors to remain part of the governance process even if they lose their function as middlemen (e.g., as oracles, namely an agent that provides information of verified real-world events to the blockchain and triggers smart contracts executions)?
- Does the DLT project ensure continued control of existing institutions over the governance of the ledger (e.g. consortium and private chains with access rights)?
- Does DLT not threaten to liberalise markets that were hitherto controlled by centralised institutions?

Is the DLT solution aligned with overall policy objectives such as reputation and performance?

Namely:

- Are there political motives at higher decision-making level that are aligned with introducing blockchain as a tool for accountability, checks and balances at lower levels?
- Are existing institutions exposed to pressure from the private sector, civil society or the international community to increase trust and transparency in their work?
- Does the solution provide efficiency gains in terms of performance which outweigh the loss in control?

If you can answer at least one of these questions in the positive, using blockchain for your development objective can be seen a valid option. It must nevertheless be pointed out that the political feasibility of DLT applications within the realm of international development cooperation becomes increasingly difficult the more vested interests are involved. Thus, a blockchain use case requiring the delegation of control from one single governmental actor will be easier to achieve than a DLT application demanding the delegation of power by several nation states. In a final step, comparing the envisioned blockchain solution and its benefits with those of other technologies is necessary:

(vii) Are there technological alternatives ?

To adopt the best possible solution for your development project, understanding the technology landscape is key. You must know whether and what technological alternatives exist that can achieve the desired outcome. If there are other technologies which can deliver the same results as a blockchain, it is essential to understand exactly why DLT should be favoured. As with blockchain, existing technologies may also create friction and face hurdles. A comparative evaluation is therefore advisable.

To summarise, should the assessment framework have shown that using a DLT based solution provides for both added value and practical feasibility, you may want to go ahead and take a deep dive into concrete project design implications. However, should the seven evaluation segments suggest that using blockchain might not really fit your development objectives, considering other digital solutions which offer more tangible benefits to your envisaged project is advisable. Looking beyond the hype also means recognising that DLT is not a silver bullet and you do not have to rely on it at all costs to be innovative.

Designing your project

When it comes to conceptualising your blockchain project, it is essential to ensure that you leverage the hard-won knowledge of the development community over many years. A good starting point in this regard are the Principles for Digital Development, a set of nine standards established to promote effective practices in technology-enabled programmes for international development and cooperation. Endorsed by GIZ among over 100 other development agencies and actors, the Principles aim to realise the full potential of ICT including blockchain for development initiatives worldwide. The alignment of your project with these Principles will ensure that you will make the most strategic investments in digitally supported development work.

User-friendliness and involvement

First and foremost, when designing a digital development project, you will have to take a look at users' needs. Today, user adoption of blockchain is one of the greatest challenges to the success and sustainability of any given initiative, so understanding comfort levels with blockchain will be crucial for achieving social impact. Most decentralised applications are still only used by a very narrow group of people, most likely the people who are technically savvy enough and hence do not have to be guided in their exploration of the technology. For example, the most widely used decentralised applications listed on the State of the Dapps ranking page still only have hundreds to a few thousand daily users, gambling and games being the most popular. To onboard users from various industries to use blockchain, you will need to learn about users' priorities, motivations and challenges. In accordance, Digital Principle 1 emphasises that "successful digital initiatives are rooted in an understanding of user characteristics. User-centered design [...] starts with getting to know the people you are designing for through conversation, observation and co-creation."[12] Your ability to deliver services is better if you're not guessing what is and is not working, but instead make decisions based on the feedback of the prospective users themselves. The DLT design should therefore not only be easy to handle for the average user in the target environment without the need for much instruction, but also be designed with him or her. Where smartphone and Internet penetration is low, a focus on business-to-business, business-to-government or government-to-government solutions may yield more success than going into 'retail' apps for citizens.

Understanding your ecosystem

Second, the Principles consider a clear understanding of the particular challenges in a given development context as an absolute necessity for a successful use case design. Without understanding your existing ecosystem, namely, the specific needs and structures at community, regional and country level, your selected technology tool might fail to achieve relevant and sustainable impact. As Digital Principle 2 acknowledges: "Ecosystems are defined by the culture, gender norms, political environment, economy, technology infrastructure and other factors that can affect an individual's ability to access and use a technology [...]."[13] It is thus fundamental to compare and analyse how the characteristics of your envisaged blockchain solution fit and can be intertwined with the particular needs of your development environment.

Technical must-haves

Third, there are several project specific technical requirements which should always be kept in mind when designing proposals for every conceivable type of DLT use case. Even though these requirements are at a minimum level desirable in all projects, different projects and user groups will require different levels for each technical aspect for their goal.

Namely:

- Low transaction fees – the DLT solution should be able to carry out the transactions that are fundamental to the application at hand without incurring large transaction fees (e.g. due to the expense of having 'miners' secure the blockchain, as in Bitcoin's consensus algorithm Proof-of-Work). For example, an application which facilitates or is dependent on microtransactions should rely on technical characteristics which ensure low transaction fees. Removing the intermediary in transactions can come with a significant decrease in transaction fees, yet if the underlying consensus mechanism of the blockchain system is even more costly than intermediaries handling the transaction, such blockchain architecture does not seem advisable.

- Speed of transactions – the DLT solution should be able to process a sufficiently high number of transactions per second to sustain the use case (DLT with low transactions per second will not be suitable in cases where the availability of fast transaction processing is critical, e.g. payment networks). In most cases we examined, there will be a trade-off between the openness of a shared ledger and the speed with which new transactions can be verified. We have to remember that blockchain systems which by now hold significant value in assets are fundamentally adverse environments. This means that participants will try to extract value from these systems in cases where they can expect not to be punished for it. By making sure that only a limited number of trusted entities can participate in the verification of transactions, we can lower the possibility that networks will be attacked. By allowing unknown actors to verify transactions we open the network to higher risk, which can be mitigated with more costly consensus mechanisms.

- Scalability – the DLT solution should be able to scale sufficiently to meet anticipated demand without becoming too slow, too expensive, or too vulnerable to cyber attacks. In this sense, scalability results as a product of the previous two technical aspects and should be thought of carefully even in the piloting phase. In the words of Digital Principle 3, "designing for scale means thinking beyond the pilot and making choices that will enable widespread adoption later, as well as determining what will be affordable and usable by a whole country or region, rather than by a few pilot communities."[14] As such, to be scalable, flexible governance mechanisms have to be adopted by the blockchain architecture which can easily lead to technical upgrades in times when they are necessary. As a better illustration, the summer of 2017 saw an intense debate between Bitcoin enthusiasts on how to handle increased transaction volume. The increased usage of Bitcoin had led to unsustainable costs of transactions paired with low speed. This was attributed to a block size limit added by Satoshi Nakamoto in July 2010, limiting the rate at which information is etched into the blockchain. Opponents to a block size increase argued that it only achieves temporary relief, while undermining decentralisation by increasing costs in participation. Disagreement in the community on whether or not to increase the blocksize led to a very invasive hard fork (i.e., a radical change to the protocol making previously invalid transactions valid or vice-versa) of the Bitcoin blockchain, which meant the splitting of Bitcoin into Bitcoin Cash (higher blocksize) and Bitcoin Classic (limited blocksize). Both projects to this day claim the label of Bitcoin for their project. The problem with hard forks is that they split up communities into several user groups, thereby working against healthy network effects. Changes in project mission for high stake networks are almost inevitable, therefore thinking of scalability from the outset seems worthwhile.

- Interoperability – the DLT use case should be designed and implemented in such a way that it is possible to migrate the use case to a different blockchain in the future. This should be able to happen with minimum transition costs as DLT continue to evolve (be wary of solutions that would 'lock you in' to continuing to use a particular DLT for long periods of time as this specific blockchain may not be around in a decade from now). The narrative in the blockchain community within the last few years has increasingly shifted from 'one chain (Bitcoin) to rule them all' to multiple chains which can interoperate with each other and provide niche services to their users. For example, Bitcoin might become your preferred store of value (due to its high security), while you use Ethereum to set up smart contracts and ZCash for privacy oriented applications. The technical idea behind interoperability is to parallelise chains which want to interoperate with each other and having a relay chain that coordinates consensus and transaction delivery between all these different member chains.

Privacy by design

Fourth, and predominantly for use cases in which personal data is being used, you should ensure that an individual's privacy and dignity is upheld by including do-no-harm considerations already early on in the design phase of the DLT solution. As Digital Principle 8 stipulates, development practitioners "must take measures to minimise collection and to protect confidential information and identities of individuals represented in data sets from unauthorised access and manipulation by third parties."[15] Even though a great promise of blockchain is pseudonymity, the appearance of total security of personal data is misleading. It is accurate that an individual can preserve his or her privacy as long as the pseudonym is not linked to the person behind it, but as soon as the connection is made and a correlation established, the private data can be revealed. Not only might the pseudonymous nature of most blockchains jeopardise an individual's privacy (by linking transaction and public key information, the flow of transactions between users and wallets could eventually reveal the identity of a user), it also prevents businesses from securely sharing proprietary data. The blockchain ecosystem has been zealously working on solutions to this challenge, including technical features such as zero-knowledge proofs (i.e, person X can prove something to person Y without having to transmit any information about the thing itself). In short, these technical features promise the verification of a particular actor without the particular actor having to disclose privacy-related information. Applications could, for example, be developed for insurance or credit where a user has to prove that they have a minimum level of funds without revealing the exact figure in their bank account. US bank JPMorgan Chase's Quorum (its Ethereum-derived, permissioned blockchain platform) introduced the first version of a zero-knowledge security layer (ZSL) into its enterprise blockchain. Being aware of and working with such privacy-enhancing technologies during the conception stage of your DLT project is thus fundamental to guarantee that it indeed benefits the people it wants to serve.

Multi-stakeholder partnerships

Fifth, take time to consult with other DLT development practitioners and actors when planning your initiative. Best practices and lessons learned from colleagues working in the same context as you or with experience of the issue at hand can help guide your project design. As Digital Principle 9 highlights, the identification of individuals who have knowledge that applies to your development project is core.[16] Moreover, consider working with actors from various types of organisation (e.g. local, regional or national governments, academia and civil society organisations) to incorporate a wide range of perspectives and insights into your DLT project. Careful thought should especially be put into assembling the appropriate constellation of stakeholders at the project's inception phase. A diversity of opinions and skillsets is needed to ensure the success of the project.

Selection of project partners

Given that DLT is a recent and rapidly evolving area of innovation, the pool of DLT savvy organisations and experts is still relatively shallow. True blockchain expertise takes time to develop. Even individuals with strong computer science backgrounds must invest significant time and effort to understand how DLT really function and what advantages and disadvantages they offer as compared to other technologies. There is, in short, a global talent shortage of true DLT expertise.

Beyond technical circles, the problem becomes even more acute. DLT are, at their core, social technologies. They are designed for, and can only operate successfully within the framework of interconnected economic and social systems. Designing and implementing sensible projects to deploy DLT for international development purposes therefore also requires social science expertise. This explains why blockchain startups are aggressively snapping up talent from fields like economics, political science, psychology, sociology and law. These individuals bring much needed expertise on how humans (and their machines) interact with and adapt to new technology-mediated modes of communicating, transacting and contracting with one another.

Against this backdrop, it is unsurprising that consortium models are the most common partnership structure observed in the DLT space. Consortia allow actors to share scarce talent resources and mutually benefit from common research efforts. Blockchain consortia often form around shared sectoral (e.g. finance) or use case (e.g. supply chain management) interests. They are comprised of various mixes of corporate, startup, academic, government and non-profit actors.

Example

Joint partnership structures are also the norm for carrying out specific 'proof-of-concepts' (PoC) and pilots in the DLT space. For instance, a PoC aiming to test the viability of DLT as a means of tracking the carbon footprint of specific products and services might include:

- a DLT startup or foundation which provides the underlying technology;
- corporate actors who wish to track their carbon footprint;
- a non-profit or for-profit organisation with expertise in carbon measurement and certification;
- funding bodies with a mandate to promote climate accountability;
- a governmental or intergovernmental agency with expertise in carrying out environment-related projects;

- a set of local partners in the countries where the PoC is to be carried out;
- a contractor to oversee user-centered design;
- a set of independent experts to advise on regulatory environments, DLT configuration options, economic and political considerations, etc;
- a consultancy to manage the workflow of all of the above.

Selection of DLT protocol

Sixth, when selecting a vendor of a DLT protocol, you have to be aware of the fact that there is fierce competition in the blockchain space between competing projects. From Bitcoin, Ethereum, Ripple and other leaders all the way down to the least-known protocols, each of these projects has its own technical infrastructure and tightly knit community of highly engaged developers, investors, users, fans and critics.

Accordingly, it is best to view the different DLT projects not as protocols but as ecosystems. In such ecosystems, there is almost always a direct link between the project's broader societal adoption and the personal wealth of the individuals who build and promote it. This is as true of public, permissionless DLT as it is of private, permissioned ones. While the token-based financing model of many projects allows them to invest in innovation and proof-of-concepts, one should ensure to avoid conflicts of interest and avoid undesirable lock-in effects. An 'open source' project is no guarantee against lock-in. A broad set of blockchain ecosystems can be reached through the following online groups:

Examples of listservs (mailing list servers):

- UNOPS blockchain listserv
- Blockchain Bundesverband slack
- World Bank blockchain listserv
- Blockchain for social impact slack

Ultimately, the decision to use one particular DLT protocol over another should be made on the basis of which protocol best meets the technical design and functionality requirements of your use case in the environment where it is to be deployed.

Planning for sustainability

Seventh, you will have to design for the sustainability of your blockchain solution. Following Digital Principle 4, a sustainable initiative is "one that is easy to maintain and flexible enough to adapt to a changing ecosystem and to evolving user needs."[17] When planning for implementation, you will have to identify how using DLT will affect the sustainability needs of your development context. If the planning and implementing actors will not own the blockchain application in the long run, budget and plan the transition to local ownership. This might include handover processes such as management, system maintenance, development and monitoring activities etc. In addition, calculate the total cost of ownership of the project and identify options to sustain it financially – also in the event that the initiative scales.

Using open standards and open source

Eighth, to increase collaboration in the digital development community and to avoid 'reinventing the wheel', you may want to use open standards, open data, and open innovation. As Digital Principle 6 rightly points out, too often scarce development cooperation resources are invested in new software code, methods of data collection and tools which then remain locked away by licensing fees etc. and cannot be used beyond the specific project they were designed for. Hence, to make sure that the blockchain-powered solution you aim for creates positive impact for your particular development context and beyond, "design and develop your [DLT] tool using open approaches so that users, stakeholders, and the digital development community all benefit."[18]

Tech convergence

Finally, you might not want to dismiss the potential of linking other technologies to your DLT solution. In many cases blockchain in its application can be combined with other technologies such as sensor networks, artificial intelligence and fintech applications like mobile money, among others. In fact, technology convergences are an essential part of how the strengths of blockchain can be accentuated. Hence, in some cases you might start designing a blockchain project, but when scrutinising users' needs, you may come to the conclusion that a hybrid solution encompassing DLT and, for instance, machine learning or IoT applications would strongly benefit the purposes of your development objective. The need to pay attention to tech convergence also finds itself reflected in Digital Principle 7 which underscores that "innovation can also mean repurposing existing tools in a new way or adding additional features or functionality."[19]

Specific risks of implementing DLT projects

Once your project has been designed, there are a few potential risks to consider when it comes to implementation. From the IT security point of view, a DLT has a different risk profile compared to an ordinary database. The distributed architecture brings better availability and resilience to blockchains, but at the same time confidentiality is harder to realise and typically needs to rely on cryptographic protocols only. In addition to IT security risks, DLT often come with tokens representing economic value. Those tokens introduce a whole new class of risk that are known from other financial assets.

Volatility of tokens

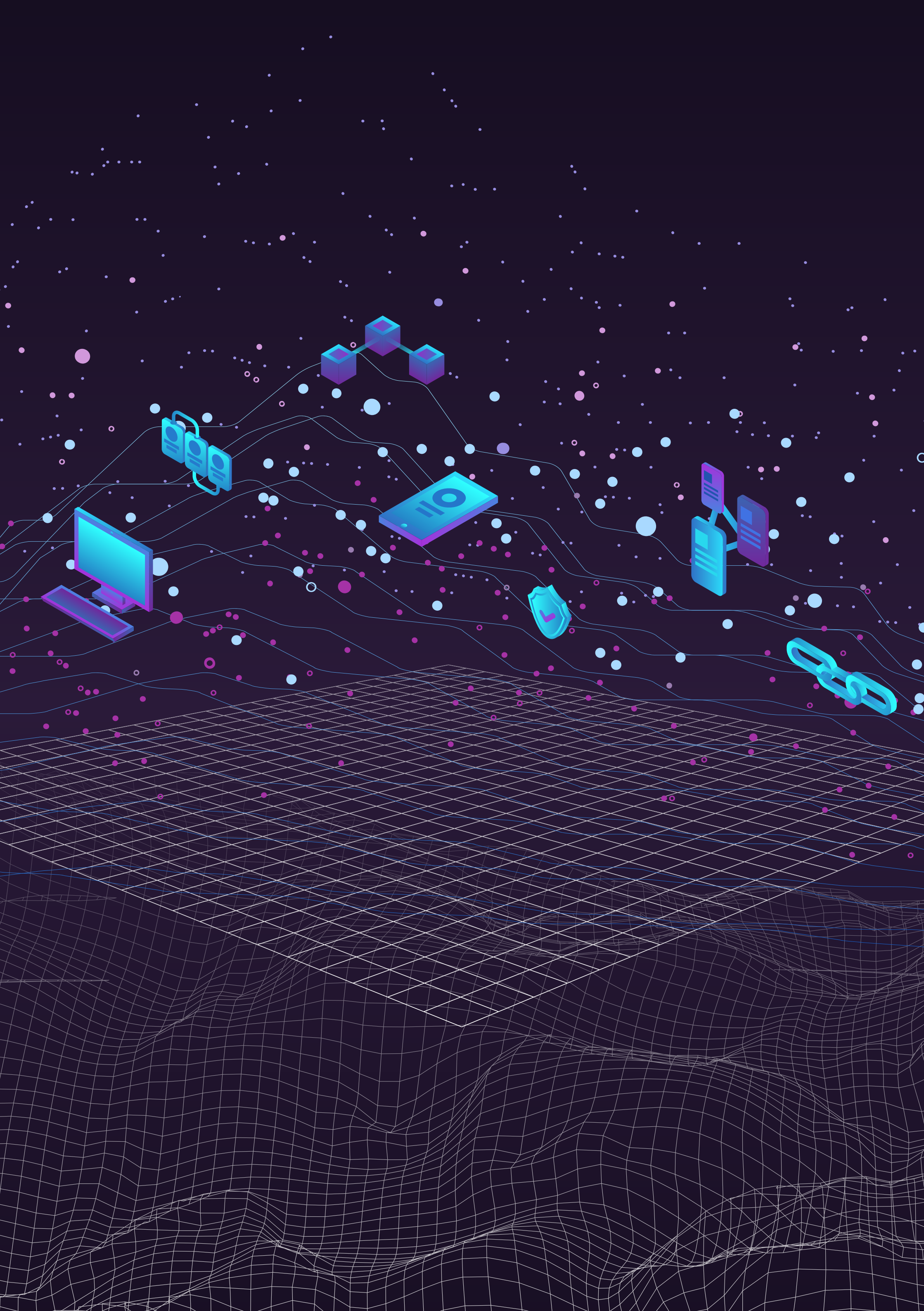
Many blockchain tokens are traded similarly to stocks on public markets, i.e. on crypto-exchanges. Unlike company stocks, most crypto-assets come without the fundamentals that allow an objective basis for their valuation, like revenues, staff, assets and customers. This exposes tokens to fluctuate wildly with market sentiment. Even the largest and most stable cryptocoin bitcoin has an average daily volatility of around 5%. The practical impact of these risks can be minimised in blockchain for sustainable development use cases by minimising the amount of time during which a user's value is stored in the form of a token (i.e., by trading it back into a fiat currency as soon as the transaction is complete). This is what many blockchain-driven international remittances services rely on. Alternatively, so-called 'stablecoins' like Tether offer another solution: their value is pegged to a fiat currency through a company which guarantees exchange at that rate. The stability of such tokens can be trusted as long as we trust in the governance of that company implementing the currency peg.

Insider trading and conflicts of interest

Given the limited supply, the value of tokens increases with their widespread adoption. For that reason, founders of blockchain projects that issued a token have a financial motivation in having their token ecosystems widely used. This can be beneficial as it may encourage these start-ups to significantly invest their own resources in proof-of-concept or pilot projects. At the same time, we need to pay attention to compliance rules and potential conflicts of interest when implementing projects with these entities. Imagine, for instance, a public sector stakeholder who is involved in a decision that could boost the value of a specific token. To avoid conflicts of interest the decision-maker should avoid holding such tokens on his or her own account or passing insider information to other investors. Besides strict observance of compliance rules, risks can be mitigated by using ecosystems that do not generate their own tokens but instead use existing crypto-assets with high market cap like Ethereum, or a stablecoin pegged to a fiat currency. Also permissioned blockchains such as consortium blockchains can run without creating their own tokens. Timestamping applications in turn are less critical because they merely use the blockchain to reliably store data on it, which does not influence supply and demand of tokens.

Regulatory risks

While timestamping applications mainly need to deal with privacy legislation in case the stored data can be linked to individuals, other blockchain applications may be subject to financial market regulatory regimes. Typically this means you must satisfy 'by analogy' the key rules and policies of the regulatory regimes that apply to the most closely associated category of non-digital assets. For example, if your DLT use case involves money transfers using cryptocurrencies, you should look to apply, by analogy, the rules that apply to fiat money transfer services, which may include KYC (know your customer) and AML (anti-money laundry) rules. With this nascent technology, the legal environment is steadily evolving, and some law firms are specialising on providing legal advice on crypto-projects to avoid regulatory concerns.



Chapter 5

Looking ahead

In this report we have discussed a selection of promising DLT use cases for societal good, cross-cutting all sustainable development dimensions of the 2030 Agenda. The insights from looking at these applications suggest that most added value is created by more transparency, reduced market friction, system resilience as well as smart incentivisation of desired outcomes. Yet, with the technology still in its infancy, experience with implementation in the field remains scarce. Many of today's blockchain initiatives are early-stage and still need to demonstrate viability in real-life settings and at scale.

Even though the general sentiment regarding blockchain remained largely optimistic in the corporate world in 2018 – a survey by Deloitte found 74% of executive teams in large companies seeing a compelling business case for using DLT – some voices in the tech community operating in the international development sphere have come to adopt more sobering views.[20] In a recent blog, MERL Tech (a platform discussing the use of technologies for Monitoring, Evaluation, Research and Learning in the humanitarian and international development field) analysed 43 blockchain use cases and did not find a single application that could prove its impact with reliable data.[21] These findings may be attributable to a lack of transparency in projects, their early stage character or to actual failures in implementation. 43 is also a significant but hardly comprehensive sample. Bitcoinlist.com indexes over 80,000 blockchain initiatives, of which 6,000 projects are still active, and PositiveBlockchain.io compiles a total of 650 DLT projects aimed at social impact.[22] Failure rates for tech startups range around 90% according to the Startup Genome Report, and yet – those few that do survive and become successful fundamentally transform the way we do business, the way we communicate and the way we develop as societies.[23] [24] Already today a handful of DLT startups have taken off and are generating significant revenues using their blockchain solutions, including Ripple which has set out to disrupt interbanking business as we know it, and ConsenSys which is tackling a number of other sectors with its 1000+ employees worldwide.

This is the reason why we still deem it worthwhile looking into the most promising use cases of the technology through proof-of-concepts and pilot projects. Most startups target the obvious business-to-customer and business-to-business markets, while DLT in public sector mandates remains widely unexplored. One of the low hanging fruits in public sector blockchain applications is 'timestamping' for accountability on a public ledger. It is technically very feasible and has already been tested in practice. While it is true that timestamping is unlikely to disrupt entire institutions, it certainly provides a guarantee that data is not manipulated once published and strengthens accountability pressures. This certitude can, for instance in an eProcurement system, give bidders the assurance that their competitor's bids have not been altered to win the contract.

Beyond simple timestamping applications and the five use cases outlined in more detail in the previous chapters, we see the merits of distributed ledgers in the implementation of a variety of checks and balances for good governance and, at multilateral level, for mutual accountability between states with regard to transactions enforcing international agreements. Therefore, looking ahead and despite blockchain's early stage of development, we see genuine value in investigating the potential of DLT in the following multilateral settings:

- Trade, in particular mutual accountability and automation in customs procedures
- Climate, in particular international interoperability in climate (e.g. carbon) incentive schemes
- Financial inclusion, in particular eKYC standardisation and privacy
- Taxation, in particular VAT and international tax compliance
- Governance of the data economy, in particular data sharing using APIs and DLT based regtech

We are well aware that this will be an ambitious undertaking, notably considering that all of the above outlined fields of application encompass significant political will as well as technical challenges. Yet, history has come to tell us that solutions to great challenges tend often to be found beyond existing institutionalised mechanisms.

Blockchain thinking

Thinking beyond institutions and middlemen, thinking along the lines of markets and incentives, thinking big and globally, decentralising decision making, crowdsourcing, accountability, enabled by the Internet and various other technologies: these are elements of 'blockchain thinking'. The most radical scenario for a new form of governance is fully distributed, trustless and permissionless. Questioning all centralised elements may be a good starting point to foster innovation in governance. In a second step, however, when we want to design solutions that actually work and that serve actual needs, we may need to backtrack from full decentralisation, and invite a few centralised trusted functionalities back in. Technically speaking, this may mean abandoning the idea of a permissionless blockchain in favour of a hybrid solution encompassing not only a distributed ledger but also other technologies.

Questioning all centralised elements may be a good starting point to foster innovation in governance.

For us as development practitioners, problem-centered innovation will always stand at the forefront of our actions. Hence, we will continue exploring new pathways to make the transformational vision of the 2030 Agenda become reality. It is our conviction that technology and innovation will play a key role in this endeavour. We are ready to question existing governance frameworks and scrutinise how emerging technologies, such as blockchain, AI, sensor networks, and fintech applications can contribute to international problem-solving.

The architect Louis Sullivan once coined the idiom 'form follows function'. In the architecture of economy and society, we want to design solutions that serve functions of sustainable development. Emerging technologies are providing us with new building materials to do so. The Internet and Blockchain in particular appear to be building materials that open new avenues to decentralisation, market and incentive mechanisms. Leveraging this new building material, we can imagine the architecture of tomorrow's society as being a more decentralised one.

Key takeaways

→ **Blockchain is not a silver bullet.** The added value of DLT has a specific scope that needs to be evaluated within the area of its application.

→ **Blockchain use cases are in their infancy.** Most projects for real-life applications are still in research and proof-of-concept stage with very low adoption rates.

→ **Pilot projects can validate claims for added value.** Given the current maturity level of blockchain, projects using DLT within the international development sphere will most likely be pilot projects and should be used to learn and scrutinise claims of added value.

→ **Human-centered design is key.** Instead of a technological solution seeking a problem, user and problem-centered design in line with the Principles for Digital Development is essential to ensure relevance and success of any implemented solution.

→ **Look beyond blockchain.** To best address needs, a converging solution of various technologies may be the most suitable way forward; this may include blockchain, traditional fintech, databases, AI, sensors or others.

→ **'Blockchain thinking' is a thing.** Blockchain thinking is about questioning established institutions, cutting out intermediaries and gatekeepers, decentralising and crowdsourcing to the maximum, considering incentives and market mechanisms, in order to find new, more decentralised solutions. Blockchain thinking may prove valuable, regardless of whether the technical implementation of the solution actually employs a blockchain or not.

→ **Never cease to innovate.**

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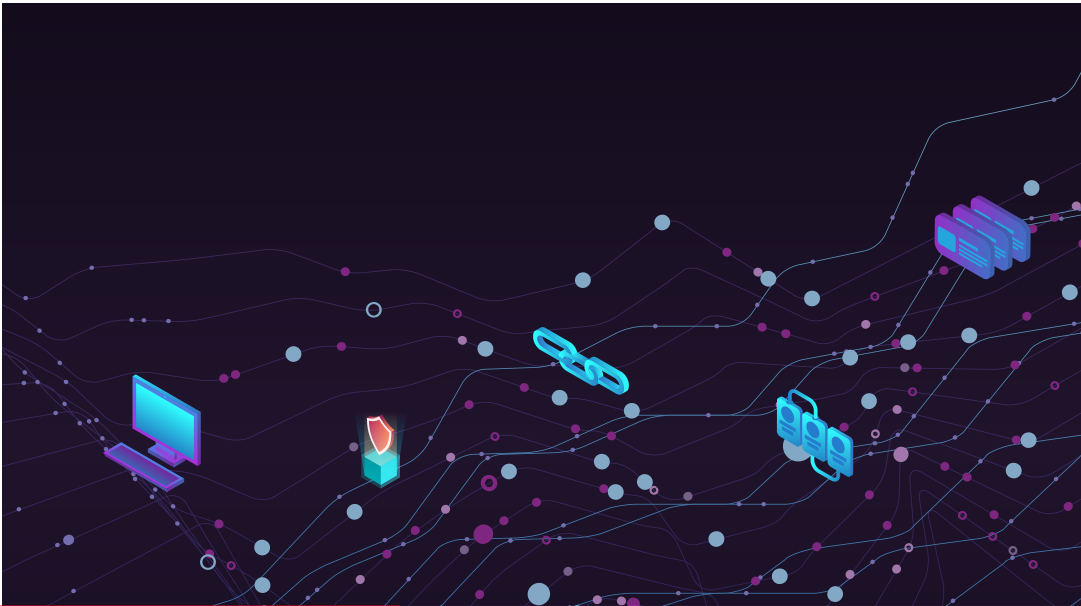

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