Tokenization of Infrastructure

A blockchain-based solution to financing sustainable infrastructure

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David Uzsoki

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Written by David Uzsoki

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Abbreviations

AML	anti-money laundering
ICO	initial coin offering
IoT	Internet of Things
IP	Internet Protocol
IT	information technology
KYC	Know Your Client
NAV	net asset value
REIT	real estate investment trusts
SRC	SwissRealCoin
STO	security token offerings

Executive Summary

"Nothing is more powerful than an idea whose time has come."

Victor Hugo

The emerging fintech solutions have demonstrated that technology and digitalization indeed have an important role to play in addressing the inherent limitations of our current financial system. The long-overdue digitalization of finance can result in better transparency, and it can lower transaction costs by eliminating many of the intermediaries needed to facilitate financial transactions. It can also lower the cost of financing and make financial services more inclusive.

Blockchain-based technologies will play an important role in the digitalization of finance. As the large number of blockchain start-ups demonstrate, the underlying technology has a wide range of use cases, many of which go beyond finance. While the long-term viability and adoption of these ideas remain to be seen, even skeptics agree that blockchain has the potential to provide simple solutions for some of the fundamental problems that businesses and industries have struggled to address in an efficient manner.

Improving efficiency throughout the financing and operation phases is particularly important for sustainable infrastructure projects, such as renewable energy and green buildings. They are often more difficult to finance than their traditional counterparts due to the higher upfront costs and higher perceived technology risks associated with more environmentally friendly solutions. Therefore, sustainable infrastructure projects often rely on some kind of public support to make them financially viable. This includes subsidies, feed-in tariffs, guarantees and other third-party de-risking instruments.

While the cost of green technologies has been on a downward trend, the question still remains how to decrease the cost of capital to make sustainable infrastructure more financially attractive. In other words, how can the risk premium priced in by investors be reduced so the revenue streams generated by the project can more comfortably cover its costs. This is the fundamental challenge of financing sustainable infrastructure that tokenization aims to address.

Tokenization refers to the digitalization of real-world assets or financial instruments using blockchain technology. By tokenizing the equity and debt used for financing an infrastructure project or portfolio, the financial viability of the underlying asset can improve considerably. These tokens are classified as financial securities by regulators; hence, issuers have to comply with all the relevant financial regulations.

The Value Proposition of Tokenization

The tokenization of sustainable infrastructure can address some of the fundamental challenges in the financing of the asset class, such as lack of liquidity, high transactions costs and limited transparency.

1. LOWER TRANSACTION COSTS

Cost savings related to the public listing

As per the Organisation for Economic Co-operation and Development (2017), the average underwriting fee for an initial public offering (IPO) with a size of less than USD 100 million can be 9 to 11 per cent in the United States. PricewaterhouseCoopers (2012) estimates that the underwriting fees

can range between 49 and 60 per cent of the overall listing costs for this deal size. In other words, the cost of going public can be between 15 and 22 per cent of the transaction value. This number might vary somewhat for listed infrastructure; however, it is a rough indication of the costs associated with accessing liquid public markets. As tokenization eliminates most of the financial, legal and regulatory intermediaries, the transaction costs are significantly lower. Based on the current solutions available, the experts interviewed estimate that the overall fee for tokenization should be below 5 per cent as the blockchain sector matures.[1]

Cost savings related to transactions on the secondary market

Non-listed real estate investment trusts (REITs) usually have a front-end load of between 10 and 15 per cent of the transaction (Tokenestate, 2018). It is a one-time commission charged when investors purchase the fund. This type of fees is not applicable for tokenized assets, as investors can easily buy the tokens on a liquid secondary market.

For listed real estate investment trusts, investors have to pay the brokerage commission for equity transactions. For larger institutional investors, it can be as low as 0.20 per cent; for retail investors, fees can reach 2 per cent for the purchase and 2 per cent for the sale of the securities (UBS, 2018). Transaction fees of token exchanges usually range between zero and 0.25 per cent. For example, the largest crypto exchange by volume, Binance, is charging 0.10 per cent to retail clients (Binance, 2017).

Traditional listed securities have to go through a range of intermediaries, some of which still have a manual component involved in how transactions are processed. This explains why our current financial processes are unable to facilitate small-scale transactions in a frictionless manner, excluding retail investors from many of the asset classes. Also, by eliminating intermediaries, token transactions also have a significantly lower counterparty risk.

Cost savings related to the operation of the entity managing the asset

Smart contracts can automatize infrastructure fund management way beyond the existing solutions available. They can deliver efficiency gains in operations both at the level of the project and in the entity managing the asset.

Smart contracts can facilitate client reporting, collecting and sharing data from Internet of Things devices, while improving transparency, as discussed further below. Smart contracts can also automatize financial transactions, including new incoming funds from investors, drawdowns, capital calls from investors and redemptions.

2. BETTER TRANSPARENCY

Blockchain's main promise of being a "trust machine" is that it can improve transparency and accountability for infrastructure projects by orders of magnitude. It can facilitate and improve the monitoring of financial, operational, social and environmental performance.

The data generated by Internet of Things devices, such as smart sensors, can reduce the costs associated with the planning and preparation of projects. It will make key assumptions used in project finance modelling much more accurate, including forecasting future revenues and costs. This will allow sponsors to decrease the contingency costs that they need to set aside for construction. Also, the size of liquidity and working capital facilities can be lower if revenue and cost patterns can be forecast more accurately. All of these factors will contribute to a lower cost of financing and better overall bankability of the project.

[1] Please see the Acknowledgements on page iii for a list of experts interviewed for this report.

By improving the quantity and quality of information available, the asset will also have a higher valuation during its operating life. Investors expect assets to sell for a discount in 10 years if they are not on a blockchain. As in this case, the buyer would need to perform due diligence the traditional way, which is not only costly, it might not be as accurate as what would be the case for a tokenized project.

3. ENHANCED LIQUIDITY

Infrastructure is an illiquid asset class. Transactions in alternative assets are slow and involve a large number of intermediaries. Transacting parties are required to conduct a lengthy due diligence process and go through a large amount of paperwork. In traditional private deals, it can take months to sell a position and cost about USD 10,000–20,000 to re-paper the transaction (Stein, 2018).

Through tokenization, the liquidity of the asset class can be improved by orders of magnitude. It can enable the creation of secondary markets and eliminate the need for the steep liquidity premiums currently priced in by lenders and other investors in the space. According to Josh Stein, CEO of Harbor, the illiquidity discount to the net asset value (NAV) of the fund is estimated to be 20–30 per cent based on academic research, but in reality it can reach 40–60 per cent. In other words, if you can unlock liquidity, you can deliver tremendous value (Stein, 2018).

4. ACCESS TO ALTERNATIVE SOURCES OF CAPITAL

Tokenization can crowd in a range of non-traditional capital providers into infrastructure, including retail and other smaller-scale investors. The asset class is currently not accessible to non-institutional investors due to high minimum investment sizes, high relative transaction costs and stringent client suitability requirements due to the illiquid nature of these investments.

Tokenization enables fractional ownership of the asset's value and automates many aspects of the client on-boarding process. This decreases transaction costs and makes smaller investment sizes financially viable for infrastructure funds and other entities issuing tokens. Tokenization therefore improves investor access to infrastructure projects both at the time of issuance and on the secondary market.

5. LESS COUNTERPARTY RISK THROUGH DECENTRALIZATION

Decentralization is one of the key value propositions for most blockchain-based solutions. The benefit of decentralized systems is that there is no central point of failure. In a financial context, this means that there is less counterparty risk, as systems can operate without the need to trust a third party.

Counterparty risk is arguably the most prominent risk in financial transactions. This can be seen by the industry's reliance on credit ratings. Through tokenization of infrastructure, one still has counterparty risk as, in the case of debt for example, the borrower can still default on its debt obligations. However, tokenization eliminates the counterparty risk associated with financial intermediaries that transacting parties normally need to rely on in the case of traditional financial transactions.

6. INCREASED TRANSACTION EFFICIENCY

Secondary market transaction of private securities can take weeks or even months to complete. For listed securities, settlement times are usually three business days (T+3), assuming that the transaction is matched and securities are delivered without any delays. As operations staff in banks can confirm, this is not always the case, as it can take several days of manual intervention from different parties to settle a single trade.

Most of the tokenization initiatives reviewed for this paper are based on the Ethereum blockchain. At the time of writing, the transaction time of the Ethereum blockchain is almost instantaneous, with a median waiting time of 27 seconds (ETH Gas Station, n.d.). As transactions are executed on a peer-to-peer basis without a centralized clearing house, trades are always matched, and therefore it is impossible to have delays in delivering the underlying security token. In addition, crypto exchanges operate 24 hours a day and seven days a week, providing liquidity and enabling price discovery around the clock.

7. OVERCOMING THE LIMITATION OF SMALL PROJECT SIZE

Financing small-scale projects

Access to cheap financing is one of the main barriers of financing small-scale infrastructure. Private sources of financing are often not economical below a certain project size due to the high transaction costs involved. This is one of the reasons why small infrastructure projects have to rely on public financing and struggle to attract private capital at scale. Current initiatives to bundle these projects to increase the overall ticket size for investors have had mixed success.[2] At the same time, small-scale projects often deliver the most economic and social impact per dollar spent.

By tokenizing small-scale infrastructure, due diligence and transaction costs can be significantly decreased, as outlined earlier. This enables cost-efficient bundling through tokenizing a portfolio of assets or even individual projects.

More targeted exposure during portfolio construction

If there is no minimum project size, investors would be able to construct portfolios with a very specific type of infrastructure exposure. For example, an investor might want to build a portfolio, buying infrastructure in city A, profiting from a price increase, and short selling infrastructure in city B, profiting from a price decrease. Tokenization can enable a completely new level of portfolio construction with the ability to gain very specific investment exposure.

The Challenges of Tokenization

Tokenization can only realize its full potential in financing sustainable infrastructure if the main regulatory and technical challenges are sufficiently addressed.

REGULATORY CHALLENGES

The lack of regulatory clarity for tokenized assets is becoming a major obstacle for the wider implementation of this new asset class. While some jurisdictions are moving faster than others (Provasoli, & Mokhniev, n.d.), there is still a lot of uncertainty around fundamental questions such as how security tokens can be compliant with relevant financial regulations. This poses a problem for the whole financial value chain of digital assets, including issuers, custodians, exchanges and investors. The challenge is to find a framework where the key value proposition of tokenized assets is not significantly diminished or lost in the process of complying with regulations designed for traditional financial instruments.

TECHNICAL CHALLENGES

There has to be a trusted way to ensure consistency between the on-chain tokens and the underlying off-chain assets. While smart contracts and software always execute in a predictable manner, in our

[2] For example, see the *West Coast Infrastructure Exchange Case Study*: https://carleton.ca/3ci/wp-content/uploads/WCX-2014-Case-Study_Final.pdf

off-chain world there could be a range of unexpected events that need to be monitored and reflected on the blockchain accordingly.

Currently, most security tokens are based on the Ethereum blockchain, which has had some notable achievements, but also a few failures. There is still some hesitancy among institutional investors about its reliability, as at the end of the day it is a work-in-progress product with a three-year track record.

Tokenizing Real Assets: Examples from Switzerland

The following are some of the main start-up initiatives in Switzerland that are working on solutions for security tokens and the tokenization of real assets.

Tokenestate enables companies and real estate asset managers to issue and efficiently manage blockchain-based digital securities through its platform. Infrastructure has very similar properties to those of real estate; therefore, the solutions proposed by Tokenestate can be easily applied to the tokenization of infrastructure assets.

Smart Valor's mission is to democratize access to wealth (Smart Valor, 2018). It has recently launched its VALOR Platform, a decentralized marketplace for tokenized alternative investments, such as venture capital, private equity, hedge funds, real estate and commodities. This USD 7 trillion multi-asset class is currently only accessible for high-net-worth individuals and institutional investors. Through the VALOR Platform, anybody will be able to invest in these assets. As tokenized infrastructure is considered to be a security, there is a pressing need for exchanges, such as Smart Valor, that are fully regulatory compliant for security token trading.

Mt Pelerin is in the process of becoming a fully regulated and compliant blockchain-based bank. It will tokenize its entire balance sheet: assets, liabilities and equity. It has also developed its own open source security token standard. The list of parameters of the standard demonstrates very well what functionality all security tokens, including tokenized infrastructure, must have to ensure that token holders are treated the same way as traditional shareholders.

SwissRealCoin (SRC) is a security token linked to a portfolio of Swiss commercial real estate. It is issued by Crypto Real Estate Ltd, whose focus is to automate real estate asset management. While the underlying portfolio of SRC is commercial real estate, the proposed token structure could be easily applied to any infrastructure portfolio due to the similar characteristics of the two asset classes. Instead of tokenizing an equity stake, SRC represents a perpetual subordinated non-interest-bearing bond with voting rights.

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1 Tokenization of Infrastructure

> "It is a machine for creating trust."
>
> ***The Economist*** (2015b), describing blockchain

Technological innovation has disrupted traditional business models and industries, but its impact on the financial sector has been limited so far. Financial market participants still rely on archaic information technology (IT) systems and inefficient, costly processes for even the simplest financial transactions. These shortcomings became more apparent as more stringent financial regulations and capital requirements came into force after the 2008 financial crisis. This resulted in a decrease in available capital flows and higher cost of financing, especially for long-term illiquid assets such as infrastructure.

The emerging fintech solutions have demonstrated that technology and digitalization indeed have an important role to play in addressing the inherent limitations of our current financial system. The long overdue digitalization of finance can result in better transparency, and it can lower transaction costs by eliminating many of the intermediaries needed to facilitate financial transactions. It can also lower the cost of financing and make financial services more inclusive.

Blockchain-based technologies will play an important role in the digitalization of finance. As the large number of blockchain start-ups demonstrate, the underlying technology has a wide range of use cases, many of which go beyond finance. While the long-term viability and adoption of these ideas remain to be seen, even skeptics agree that blockchain has the potential to provide simple solutions for some of the fundamental problems that businesses and industries have struggled to address in an efficient manner.

BLOCKCHAIN

Blockchain is a peer-to-peer distributed ledger technology invented by Satoshi Nakamoto in 2009 to serve as the public transaction ledger for the cryptocurrency bitcoin. It allows the transfer and storage of data without the need for relying on a third party. Each block contains a set of transactions, which are linked using cryptography. Once information is confirmed by the network, it cannot be altered without the consensus of the network and without changing all the subsequent blocks.

TOKENIZATION

Tokenization is the digitalization of an asset, where each token represents ownership of a part of the underlying infrastructure project. Blockchain enables the storage and transfer of these cryptographic tokens in a frictionless manner.

In simple terms, blockchain offers the following value proposition:

- It enables the creation of trustless systems, where transacting parties do not have to trust each other, therefore eliminating counterparty risk.
- It is an immutable distributed ledger addressing the issue of data integrity, ensuring trust in public or private records.
- It can be used to create decentralized, permissionless systems, where anybody can participate in the verification of transactions without relying on a centralized institution.

The most important component of our current financial system is trust. All financial crises have demonstrated that when trust is questioned, it can have devastating consequences on the system as a whole. Financial market participants have to rely on resource-intensive processes to maintain this trust. Blockchain can offer a cost-efficient solution to eliminate the need for a trust-based system and thus has the potential to eliminate this major vulnerability in financial markets.

Trust is also fundamental to the financing of infrastructure. Not only are these assets illiquid, but investors have to deal with a bewildering array of complexities and uncertainties. Blockchain through tokenization can address many of these financial challenges, improve valuations and decrease the cost of financing.

Tokenization can deliver a wide range of benefits—such as lower transactions costs, better transparency, enhanced liquidity, access to alternative sources of capital, decentralization and increased efficiency—while addressing the issue of scale.

Tokenizing real assets is still in its early stages; however, as the case studies in this paper demonstrate, there are already several initiatives gaining considerable traction. Some of the institutional players in the industry have recognized early the potential of tokenizing infrastructure and foresee fast adoption among asset managers. For example, Tobias Reichmuth, CEO and Founder of SUSI Partners, said at the Global Infrastructure Summit 2018 in Berlin that "in 10 years when you sell a wind farm and it is not on the blockchain you will have a discount from the buyer." Another industry insider argued that tokenization for infrastructure financing will be like emails were for physical mail—orders of magnitude faster and cheaper.

Infrastructure and other real assets are especially suitable for tokenization. As Joshua Stein, CEO of Harbor, highlighted in a recent interview, tokenization particularly makes sense for assets that are capital intensive and relatively indifferent to the identity of the investor (Stein, 2018, August). Both characteristics are true for infrastructure. Tokenization can deliver a wide range of benefits—such as lower transactions costs, better transparency, enhanced liquidity, access to alternative sources of

capital, decentralization and increased efficiency—while addressing the issue of scale. There are of course challenges, both regulatory and related to technology, that need to be overcome in order to have wider adoption. All of this will be discussed in detail in the following sections.

Improving efficiency throughout the financing and operation phases is particularly important for sustainable infrastructure projects. They tend to require a bigger upfront investment (capital expenditure) and have higher perceived technological risks compared to more traditional infrastructure.

Improving efficiency throughout the financing and operation phases is particularly important for sustainable infrastructure projects. They tend to require a bigger upfront investment (capital expenditure) and have higher perceived technological risks compared to more traditional infrastructure. As a result, there is often a need to explore innovative financing solutions to make sustainable infrastructure financially viable and attractive to investors. Tokenization can play an important role in decreasing the cost of financing, making the whole asset class more bankable.

Readers who are not familiar with this technology are encouraged to go to the Key Concepts section in the Annex (page 30), where a detailed definition is provided for the blockchain-related terminology used throughout the paper.

2 The Value Proposition

The tokenization of sustainable infrastructure can address some of the fundamental challenges in the financing of the asset class, such as lack of liquidity, high transaction costs and limited transparency. Currently, investors price in these risks by charging a premium on the cost of financing. By realizing efficiency gains in the financing process, tokenization would also improve the overall financial viability of the project.

Throughout the paper, infrastructure tokenization refers to the tokenization of the equity of the special purpose vehicle owning the infrastructure. Directly tokenizing the underlying asset would not be possible at the time of writing due to the lack of legal and technical frameworks to enable the tokenization of property rights. Therefore regulators classify all infrastructure tokens as *security tokens* subject to regulations covering traditional securities.

2.1 Lower Transaction Costs

Tokenization of real assets can result in significant savings in transaction costs. These savings are spread across the following three main categories:

- Cost savings related to the underwriting process: raising capital, legal and regulatory compliance, and exchange listing in the case of a public security such as real estate investment trusts (REITs) or listed infrastructure funds.
- Cost savings related to transactions on the secondary market: facilitating the exchange of ownership after the initial public offering was completed in the case of public securities or after the private placement for privately traded assets.
- Cost savings related to the operation of the entity managing the asset or portfolio of assets.

WHAT IS SUSTAINABLE INFRASTRUCTURE?

IISD defines sustainable infrastructure as assets that:

- Lower carbon and environmental footprints
- Steward natural ecosystems
- Move beyond compliance on core labour standards and human rights
- Trigger technological and industrial innovation
- Spur investment in education and research and development
- Increase employment
- Are financially viable
- Crowd in domestic investors and businesses
- Increase foreign direct investment
- Bring value for money for taxpayers and investors

TOKEN TYPES

FINMA, the Swiss Financial Market Supervisory Authority, categorizes tokens into three groups based on their economic function and purpose:

- **Payment tokens:** cryptocurrencies without any other functions or links to development projects
- **Utility tokens:** tokens providing digital access to an application or service
- **Asset tokens:** tokens representing assets such as participation in real physical underlyings, companies, or earnings streams, or an entitlement to dividends or interest payments; asset tokens are analogous to equities, bonds or derivatives. **Asset tokens are also called security tokens.**

Source: FINMA, 2018.

2.1.1 COST SAVINGS RELATED TO THE PUBLIC LISTING

As per the Organisation for Economic Co-operation and Development (OECD, 2017), the median underwriting fee for initial public offerings in the United States is 7 per cent of the transaction; it has recently increased to 8 per cent in Japan and China. For deals less than USD 100 million, costs can be 9 to 11 per cent in the United States, meaning that the underwriting fees for 10 companies would be equal to the value of one of the companies.

PricewaterhouseCoopers (2012) estimates that the underwriting fees can range between 49 and 60 per cent of the one-time listing costs depending on the size. The other half of the listing-related costs comprises legal fees, external auditor fees, registration-related costs, printing fees, exchange listing fees, marketing costs, human-resource-related costs and IT systems readiness costs. In other words, the overall listing fees for companies can be between 15 and 22 per cent of the transaction. This number might vary somewhat for listed infrastructure; however, it gives us a rough indication of the costs associated with accessing liquid public markets.

As tokenization eliminates most of the financial, legal and regulatory intermediaries, the transaction costs are significantly lower than those of traditional private or public security issues. This cost largely depends on the type of structure and platform used for the tokenization. Based on the current solutions available, the experts interviewed estimate that the overall fee for tokenization should be below 5 per cent as the sector matures.[1] This represents a significant improvement compared to the 15–22 per cent issuance fees discussed earlier.

Security tokens and platforms for tokenization are still at a very early stage. Experts expect fee structures to decrease further as more participants enter the market, on both the demand and supply sides of the tokenization of real assets (IISD interviews September 2018).

[1] Please see the Acknowledgements on page iii for a list of experts interviewed for this report. Subsequent references to these interviews will be cited in the text as: IISD interviews, September 2018.

2.1.2 COST SAVINGS RELATED TO TRANSACTIONS ON THE SECONDARY MARKET

Non-listed REITs usually have a front-end load between 10 and 15 per cent of the transaction (Tokenestate, 2018). It is a one-time commission charged when investors purchase the fund. For the currently available tokenization structures examined as part of this paper, there were no front-end load charges. Even as the technology matures, this is not expected to change, as tokenized assets have a liquid, well-functioning secondary market. Thus investors do not need to go through the fund manager to invest in the fund, or in the underlying infrastructure asset in the case of direct investing.

For listed REITs, all the fund-specific fees are already deducted at the fund level. However, investors still have to pay the commission applicable for equity transactions. While for larger institutional investors it can be as low as 0.20 per cent, for retail investors fees can reach 2 per cent for the purchase and 2 per cent for the sale of the securities (UBS, 2018). The size of commission depends on the financial service provider, the size of the transaction, the exchange and the country of listing. Equities listed on U.S. exchanges are generally cheaper than their European or Asian counterparts.

Transaction fees of crypto exchanges usually range between 0 and 0.25 per cent. For example, the largest exchange by volume, Binance, is charging 0.10 per cent to retail clients (Binance, 2017). On the other hand, decentralized exchanges enable peer-to-peer transactions between users and only take a small spread (the difference between the buy and sell price) of the trade. Outside of exchanges, the only applicable fee is the network fees on the respective blockchain. For example, the cost of transfer of any number of tokens on the Ethereum blockchain, where most tokenized assets are currently based, was about USD 0.015 at the time of writing (ETH Gas Station, n.d.).

Tokenized real assets would be categorized as security tokens. Currently, most crypto exchanges are not ready to list security tokens, as they would need to comply with the applicable security exchange regulations. Many crypto and traditional exchanges are currently working on enabling security token trading, including the MSX of the Malta Stock Exchange (Palmer, 2018), the Gibraltar Stock Exchange (Baker, 2018), the Swiss Stock Exchange (Bitcoin Exchange Guide News Team, 2018) and Coinbase (Zhao, 2018).

Until that happens, security tokens can also trade on decentralized exchanges, which currently operate in a regulatory grey zone, and trading capabilities are often part of the tokenization platforms. Alternatively, security tokens can be traded peer-to-peer between market participants by using an escrow account on the blockchain, eliminating the need for an intermediary (Trouche, Jolivalt, & Said, 2018). On an escrow account, a smart contract initiates the transfer of the security tokens to the buyer once a corresponding payment is made to the account.

Figure 1 illustrates how traditional listed securities have to go through a range of intermediaries, some of which still have a manual component involved in how transactions are processed. This explains why our current financial processes are unable to facilitate small-scale transactions in a frictionless manner, excluding retail investors from many of the asset classes.

Figure 1. Digital versus traditional financial transactions

Source: Smart Valor, 2018, p. 5.

On the other hand, when transferring tokens on a blockchain, in this case Ethereum (ETH), the transactions happen in a peer-to-peer, frictionless manner. For example, as demonstrated in Figure 1, Investor A sends tokens from their digital wallet to Investor B's wallet using the blockchain. Transaction fees are negligible and do not increase proportionally with the transaction size. Alternatively, token transactions can be done through an exchange. In this case, tokens would not move on the blockchain, but the exchange would simply update the balance of the transacting parties on its platform.

By eliminating intermediaries, transactions also have a significantly lower counterparty risk. This would otherwise be a material source of risk, especially under market stress, such as during the 2008 financial crisis. Therefore, counterparty risk premiums are also avoided, which would normally be priced in by the transacting partners.

SMART CONTRACTS

Smart contracts are computer programs intended to verify or implement a contract. They execute a pre-defined set of terms automatically in a trackable and irreversible manner without the need for a third party. The idea was originally described by Nick Szabo, a cryptographer, using a vending machine as an example: a specific set of input generates a predefined output.

Source: Tar, 2017.

2.1.3 COST SAVINGS RELATED TO THE OPERATION OF THE ENTITY MANAGING THE ASSET

Smart contracts can automatize infrastructure fund management way beyond the existing solutions available. They can deliver efficiency gains in operations both at the level of the project and in the entity managing the asset.

Smart contracts can facilitate client reporting, collecting and sharing data from Internet of Things (IoT) devices, while improving transparency, as discussed further below. Smart contracts can also automatize financial transactions, including investments (i.e., new incoming funds from investors, drawdowns), capital calls from investors and redemptions (i.e., outgoing funds to investors).

Smart contracts can also enhance governance by enforcing contractual agreements between transacting parties. Under a traditional setting, if one party does not meet its contractual obligations, the other party can take legal action. This can take significant time and resources. Contractual agreements implemented as smart contracts would execute automatically without the involvement of a third party.

At this stage, it is difficult to determine accurately how much tokenization will end up decreasing the transaction costs compared to existing solutions. There are indeed many initiatives in the space, but most of them are yet to launch pilots due to pending regulatory approvals. As regulators catch up, we expect to see a large number of issuances taking place, showcasing the cost savings of tokenization.

2.2 Better Transparency

Regulatory and property technologies that build on distributed public ledgers such as blockchain bring unprecedented transparency and traceability. These solutions can improve the quality and integrity of infrastructure due diligence. They can also reduce the planning and preparation costs of infrastructure projects.

THE INTERNET OF THINGS

The IoT is the concept of connecting any devices to the Internet and to each other. This also includes connecting different components of devices, such as the sensors in an airplane and even people. This giant network of connected things will be able to communicate and exchange data with each other. For infrastructure projects, IoT devices can be sensors and other appliances monitoring the operating performance of the asset.

Source: Morgan, 2014.

There is currently a large information asymmetry between the seller and buyer of infrastructure assets. Infrastructure projects generally disclose only a limited amount of information compared to listed assets. Therefore, due diligence is always a resource-intensive process for potential buyers, which is one of the reasons why transactions take a long time to complete.

By improving the quantity and quality of information available, the asset will also have a higher valuation during its operating life. As mentioned earlier, investors expect assets to sell for a discount in 10 years if they are not on a blockchain. As in this case, the buyer would need to perform due diligence the traditional way, which is not only costly but might not be as accurate as what would be the case for a tokenized project.

Tokenization can improve several aspects of how infrastructure projects are operated and monitored. With the use of blockchain, sponsors and other relevant stakeholders would not only have more information about the asset, but would have it in a verified, trusted manner. Blockchain's main promise of being a "trust machine" can improve transparency and accountability for infrastructure projects by orders of magnitude. It can facilitate and improve the monitoring of financial, operational, social and environmental performance.

Tokenized assets can also have better governance structures. Shareholders can participate in decision making through voting with their digital tokens. Relevant stakeholders, such as local communities, could also receive tokens with voting rights to have some influence in key operational decisions. This would not only improve the social acceptance of the project, but would also create a sense of ownership for a wider range of stakeholders.

2.2.1 THE POWER OF DATA

IoT devices can feed real-time project information to the blockchain, including research efficiency, occupancy rate, full history of rental income, frequency and cost of maintenance, missed payments and other usage statistics. Reliable data on key operational indicators can improve the operating performance, identify problems early and enable investors to value the asset in a more accurate manner.

With the integration of artificial intelligence and big data solutions, the information generated can be used in unprecedented ways, bringing another level of efficiency and optimization to the asset class. This includes improving the design of the asset, identifying optimal operating procedures and preventing outages before they happen.

The data generated can also reduce the costs associated with the planning and preparation of infrastructure projects. It will make key assumptions used in project finance modelling much more accurate, including forecasting future revenues and costs. This will allow asset owners to decrease the contingency costs they need to set aside for construction. Also, the size of liquidity and working capital facilities can be lower if revenue and cost patterns can be forecasted more accurately. All of these factors will contribute to a lower cost of financing and better overall bankability of the project.

2.2.2 Blockchain Oracles

As the blockchain is immutable, none of the parties can make changes to the data stored. However, there is still a need to ensure that the data used is accurate in the first place and can be trusted by all transacting parties. How off-chain data is sourced and transmitted on-chain is referred to as the oracle problem. There are multiple types of "blockchain oracles" available:

- Trusted hardware: IoT-enabled monitoring devices, thermometers, GPS systems, etc.
- Trusted authority: any type of centralized authority, such as a land registry or registration office, and other government institutions and independent auditors.
- Online and software-based sources: online prices of goods and securities, weather information, plane arrival times and delays.
- Consensus: this method is often used when a single source of data is too risky to rely upon. For example, all neighbours confirming that XY has been living in a particular place for the last 10 years or using prediction markets such as Augur[2] to find a consensus.

These trusted data feeds ensure that the blockchain has accurate information. This is especially important for smart contracts, as they rely on this data to execute a pre-defined set of conditions.

2.2.3 CHALLENGES OF BETTER TRANSPARENCY

As some infrastructure funds have highlighted, better transparency is a double-edged sword. While providing more information to limited partners can improve trust, it can also have less desirable effects. For example, the fund can experience a significant increase in the number of queries and complaints received from investors. While some of them might be justified, others might simply originate from a lack of understanding of industry best practices.

In addition, better access to information might have legal implications. The information provided might be used as the basis of legal action against the fund or the underlying assets in the portfolio. This increased legal risk would also need to be priced in accordingly, increasing the cost of financing. Therefore fund managers and infrastructure operators need to consider these implications and decide carefully what data to disclose on the blockchain.

2.3 Enhanced Liquidity

Infrastructure is an illiquid asset class. This is true for both direct investments and infrastructure funds. Transactions in alternative assets are slow and involve a large number of intermediaries. Transacting parties are required to conduct a lengthy due diligence process and go through a large amount of paperwork. In traditional private deals, it can take months to get out of a position and cost about USD 10,000–20,000 to re-paper the transaction (Stein, 2018).

Limited partners of infrastructure funds are usually locked in for 10 years and do not have access to an efficient secondary market in case they want to exit their position before the fund is liquidated.

[2] For more on Augur, see https://www.augur.net/

Through tokenization, the liquidity of the asset class can be improved by orders of magnitude.

This means that if the seller can find a buyer, they probably need to sell at a discount to net asset value (NAV), and have to go through the general partner and comply with a range of compliance requirements to facilitate the transaction.

Through tokenization, the liquidity of the asset class can be improved by orders of magnitude. It can enable the creation of secondary markets and eliminate the need for the steep liquidity premiums currently priced in by lenders and other investors in the space. According to Josh Stein, CEO of Harbor, the illiquidity discount to the NAV of the fund is estimated to be 20–30 per cent based on academic research, but in reality it can reach 40–60 per cent. In other words, if you can unlock liquidity, you can deliver tremendous value (Stein, 2018).

Due to their long-term nature and large size, project loans have high capital requirements for lending institutions. Liquid secondary markets would enable banks and other investors to easily off-load their infrastructure investments from their balance sheet. This would result in a lower cost of financing. Current financial solutions, such as securitization, are costlier and much slower than what is expected to be the case for tokenized securities.

An efficient secondary market would also enable a more accurate pricing of infrastructure projects. Price discovery can complement model-based valuation methodologies when determining the fair price of assets. It can also allow investors to better recognize market trends and identify under-performing and over-performing infrastructure sub-sectors.

2.4 Access to Alternative Sources of Capital

Tokenization can crowd in a range of non-traditional capital providers into infrastructure, including retail and other smaller-scale investors. The asset class is currently not accessible to non-institutional investors due to high minimum investment sizes, high relative transaction costs and stringent client suitability requirements due to the illiquid nature of these investments.

Alternative asset classes, such as real estate and infrastructure, can be very lucrative long-term investments when one considers their historical risk-adjusted returns. The fact that they could only be accessed by institutional and high-net-worth investors raised some concerns about the fairness of the system. Therefore the promise of tokenization to democratize finance is very much welcome and can have wider repercussions on the financial industry and overall wealth distribution. This partially explains the recent popularity of initial coin offerings (ICOs), where early stage investments finally were not limited to venture capital companies.

Tokenization enables fractional ownership of the asset and automates many aspects of the client on-boarding process. This decreases transaction costs and makes smaller investment sizes financially viable for infrastructure funds and other entities issuing tokens. Tokenization therefore improves investor access to infrastructure projects both at the time of issuance and on the secondary market.

2.4.1 REGULATORY REQUIREMENTS

The question remains whether wider access to the asset class will change as regulators catch up to asset-backed tokenization. More specifically, would client suitability and Know Your Client (KYC) regulations allow retail investors to invest in infrastructure? If yes, how much additional paperwork would that require? While the answer has been “no” for many of the existing asset-backed instruments, one has to consider that tokenization also brings in liquidity, which makes the asset class less risky for unsophisticated investors.

Indeed, security tokens, like tokenized infrastructure, require more initial due diligence from issuers, such as KYC and anti-money laundering (AML) checks, than what has been the case for utility tokens.

Security token regulations are still at an early stage or non-existent in many jurisdictions. However, when the necessary regulations are implemented, investors would need to have KYC and AML pre-clearing when buying an asset-backed token on the secondary market. The good news is that these checks can be done online and by using specific algorithms in certain jurisdictions. Existing securities regulations would be a good indication of how the regulation of security tokens will evolve in the coming years.

When trading exchange-listed alternative assets, such as REITs, on a traditional exchange, KYC and AML checks are conducted by the financial intermediary where the investor has the trading account. In the case of security tokens, the crypto exchange might fill this role, so issuers only need to do their own due diligence at the time of the ICO.

2.4.2 EXISTING SOLUTION: CROWDFUNDING PLATFORMS

Exploring ways to tap into alternative sources of capital is not a novel idea in the industry. While REITs have been around for a while, crowdfunding platforms have experienced significant growth in the last couple of years. The purpose of these platforms is to engage with investors who otherwise would not have access to these alternative asset classes. Real estate crowdfunding was estimated to be USD 3.5 billion in 2016 (Athwal, 2017), while the crowdfunding industry as a whole is expected to grow to USD 300 billion by 2025 (CFX, 2016). These numbers show that there is indeed demand from non-traditional investor groups to invest in alternative assets.

2.5 Less Counterparty Risk Through Decentralization

Decentralization is one of the key value propositions of many of the current blockchain-based solutions. The benefit of decentralized systems is that there is no central point of failure. In a financial context, this means that there is less counterparty risk, as systems can operate without the need to trust a third party. Indeed, this was the reason why Bitcoin was developed right after the 2008 financial crisis, as confidence in trusted financial institutions has been shaken.

Counterparty risk is arguably the most prominent risk in financial transactions. This can be seen by the industry's reliance on credit ratings. Through tokenization of infrastructure, one still has counterparty risk, as, in the case of debt for example, the borrower can still default on its debt obligations. However, tokenization eliminates the counterparty risk associated with financial intermediaries that transacting parties normally need to rely on in the case of traditional financial transactions.

The degree of decentralization can vary significantly depending on the type of blockchain. Permissionless systems must have a high degree of decentralization so there is no one single entity with the power to make modifications or to shut down the entire system. In the case of permissioned blockchains, the quality of decentralization depends on the governance model used. In other words, decentralization depends on how evenly the control and power structures are distributed (Kadiyala, 2018).

While Bitcoin is a good example of a public permissionless blockchain, there are many private permissioned blockchain projects gaining traction in the space. In fact, the latter is expected to be the more common use of blockchain technology, as companies cannot and should not share sensitive information on a public blockchain. Of course, information stored on a public blockchain is normally pseudo-anonymous. In other words, the transactions are public, but the identity of the transacting parties is private.

TYPES OF BLOCKCHAIN

- **Public permissionless blockchain:** Anybody can become a node (a network validator), create a wallet on the blockchain and send transactions. There is no centralized entity operating the network or having the power to change the underling protocol or shut down the system.
- **Public permissioned blockchain:** There is a centralized entity or selected entities that have the power to grant permissions to perform specific functions on the blockchain, such as validating transactions.
- **Private permissioned blockchains:** Usually set up for a specific purpose, they are controlled by a single entity. They are often used by companies who want to take advantage of the blockchain technology to streamline their internal processes.

AIRDROPS

In the blockchain context, "airdrops" refer to the free distribution of tokens to community members. A good analogy would be customers of an airline receiving miles, which can be later used for additional services within the same ecosystem.

It remains to be seen whether security tokens will be based more on a public permissionless, public permissioned or private permissioned blockchain. Current initiatives, some of which will be discussed at the end of this paper, are mostly based on the public permissionless blockchain of Ethereum.

Another interesting use case of blockchain and tokenized infrastructure could be finding ways to improve governance and stakeholder engagement. For example, local communities could receive tokens for voting free of charge as an "airdrop" in their respective crypto wallets. These tokens could later be used to have some influence on how the project is operated, and they would allow stakeholders to participate in key decisions that affect their communities. This would improve social acceptance and create a sense of local ownership for the project. Indeed, lack of social acceptance is a significant risk for infrastructure, potentially causing construction delays and disruptions during operation, both of which can have a material negative impact on cash flows and on the overall bankability of the project.

2.6 Increased Transaction Efficiency

Secondary market transactions of private securities can take weeks or even months to complete. They also involve a lot of paperwork, manual intervention and resources on both sides of the trade.

For listed securities, settlement times are usually three business days (T+3), assuming that the transaction is matched and securities are delivered without any delays. As operations staff in banks can confirm, this is not always the case, as it can take several days of calls and emails to settle a single trade. Also, listed securities can only be traded during weekdays and exchange opening hours. This could be a limitation when the market would need to price in important developments that happened outside of business hours.

Transaction times vary depending on the blockchain used and on the current transaction volumes. Most of the tokenization initiatives reviewed for this paper are based on, or have plans to be based on, the Ethereum blockchain. At the time of writing, the transaction time of the Ethereum blockchain is almost instantaneous, with a median waiting time of 27 seconds (ETH Gas Station, n.d.). As transactions are executed on a peer-to-peer basis without a centralized clearing house, trades are always matched, and therefore it is impossible to have delays in delivering the underlying security token.

In addition, crypto exchanges operate 24 hours a day and seven days a week, providing liquidity and enabling price discovery around the clock. It will be interesting to see how this constant access to liquidity will impact volatility and prices, especially for assets that have not had any secondary market previously.

2.7 Overcoming the Limitation of Small Project Size

2.7.1 FINANCING SMALL-SCALE PROJECTS

Access to cheap financing is one of the main barriers of financing small-scale infrastructure projects. Private sources of financing are often not economical below a certain project size due to the high transaction costs involved. This is one of the reasons why small infrastructure projects have to rely on public financing and struggle to attract private capital at scale. Current initiatives to bundle these projects to increase the overall ticket size for investors have had mixed success.[3] At the same time, small-scale projects often deliver the most economic and social impact per dollar spent. Therefore, their contributions to local economic development and societal well-being are paramount in both developed and developing countries.

By tokenizing small-scale infrastructure, due diligence and transaction costs can be significantly decreased, as outlined earlier. This enables cost-efficient bundling through tokenizing a portfolio of assets or even the individual small-scale projects.

2.7.2 MORE TARGETED EXPOSURE DURING PORTFOLIO CONSTRUCTION

If there is no minimum project size, investors would be able to construct portfolios with a very specific type of infrastructure exposure. For example, an investor might want to build a portfolio, buying infrastructure in city A, profiting from a price increase, and short selling infrastructure in city B, profiting from a price decrease. Tokenization can enable a completely new level of portfolio construction with the ability to gain very specific investment exposure.

If transaction costs are not an issue anymore, investors can build portfolios where they own one street in a city and short sell another street somewhere else, in the case of real estate for example. With the constant access to efficient secondary markets, portfolio rebalancing is also no longer an issue and can be done instantaneously or even in a completely automated manner.

In order to realize all the points outlined above, platforms need to be built, pilots developed, new regulations designed and existing regulations amended to facilitate the specificities of this emerging asset class. This will certainly take some time, but once we get there, the financing of real assets will improve by orders of magnitude, offering democratized access to the asset class, more efficient monitoring of the environmental footprint of projects, significantly lower transaction costs and fewer intermediaries, and will enable the financing of small-scale infrastructure projects.

[3] For example, see the *West Coast Infrastructure Exchange Case Study:* https://carleton.ca/3ci/wp-content/uploads/WCX-2014-Case-Study_Final.pdf

3 The Challenges of Tokenization

3.1 Regulatory Challenges

The lack of regulatory clarity for tokenized assets is becoming a major obstacle for the wider implementation of this new asset class. While some jurisdictions are moving faster than others (Provasoli, & Mokhniev, n.d.), there is still a lot of uncertainty around fundamental questions such as how security tokens can be compliant with relevant financial regulations.

Many market participants have developed their own proposals for a security token standard, such as Mt Pelerin and Tokenestate, as discussed in more detail at the end the paper. The purpose of a standard is to identify how tokens can comply with security regulations in their respective jurisdictions. These regulations were designed with traditional securities in mind. Therefore, there is a need for a hybrid token structure with off-chain and on-chain components to ensure compliance. The challenge is to find a framework where the key value proposition of tokenized assets is not significantly diminished or lost in the process. The current proposals for security token standards are still at an early stage and are expected to evolve considerably over time.

Another regulatory challenge is that some of the entities owning a portfolio of assets should be classified as a collective investment scheme. This requires another set of approvals and compliance with the more stringent regulations governing investment funds. As in most jurisdictions, there has not been a precedent for crypto funds getting all the necessary approvals; it is to be seen how accommodating regulators will be in providing them the green light to accept investor funds.

This also raises the question of the availability of qualified custodians for digital assets. For example, FINMA, the Swiss financial regulator, requires investment funds to designate a FINMA-authorized custodian bank for holding client assets (FINMA, 2019). Currently, there are only a few emerging

qualified custodians for digital assets. However, their numbers are expected to increase in the future, as there are several financial institutions looking into this now.

For example, SIX Swiss Stock Exchange plans to be one of the first to offer fully integrated end-to-end custody, trading and settlement services for digital assets. According to Thomas Zeeb, Head of Securities and Exchanges at SIX, "The digital space currently faces a number of key challenges. These include the absence of regulation that ensures official safety, security, stability, transparency and accountability – all of which contribute to a lack of trust. The challenge is less in the trading of assets but rather in the custody and asset servicing" (SIX, 2018). SIX is expected to start rolling out its digital services mid-2019, but it is not clear how soon custody solutions will be implemented.

Also, property rights are not yet tokenizable due to the lack of legal and technical framework to enable on-chain land registries. In other words, tokens cannot represent a legal ownership of an asset in a way that is recognizable in court. Instead, issuers need to create a special purpose vehicle off-chain, which becomes the legal owner of the underlying asset and issues its equity tokens.

On the other hand, some experts interviewed argued that there is no need to have tokenizable property rights, as investors would not want to own a square metre of a power plant, but rather a part of the project company operating the power plant.

The question is how much tokenized infrastructure will lose its appeal as regulations catch up to this emerging asset class.

Democratization of finance is one of the key value propositions of tokenization, as discussed earlier. Lower transaction costs and fractional ownership of the asset's value enable retail investors to access investment opportunities, which was not possible in the past. However, the question remains how this will change once regulation catches up to this new technological phenomenon. Infrastructure will still be an alternative asset class, requiring specific expertise and client sophistication to understand the inherent risks that can have an impact on valuations and returns. Client suitability assessments will still be required and might limit or prohibit retail investors' access the asset class. However, it is important to note that tokenized infrastructure can be considered as a liquid asset now, which makes a significant difference from a client suitability perspective.

It may take some time before all the regulatory uncertainties outlined above are resolved. On the other hand, jurisdictions that are faster to address them will experience significant growth and innovation in the digital asset space. The question is how much tokenized infrastructure will lose its appeal as regulations catch up to this emerging asset class. Some of the inefficiencies and costs in the current financial system are due to the strict regulatory compliance requirements, especially when taking client deposits and servicing non-institutional clients. There is indeed a risk that, once tokenized real assets become fully compliant with financial regulations, they will end up with higher transaction costs and be accessing the same pool of capital as their traditional counterparts. Even under this scenario, digitalization of infrastructure can still deliver material benefits to the asset class, including liquidity, transparency, decentralization and enhanced efficiency.

3.2 Technical Challenges

There are indeed some technical challenges involved in the tokenization of real assets. However, they seem to be easier to address than the regulatory challenges discussed earlier.

In the case of asset-backed tokens, there has to be a trusted way to ensure consistency between the on-chain tokens and the underlying off-chain assets. While smart contracts and software always execute in a predictable manner, in our off-chain world there could be a range of unexpected events, which need to be monitored and reflected on the blockchain accordingly. For example, buildings can burn down or power plants can have disruptions during operation due to a heat wave or low social acceptance. Trusted and secure "oracles" are needed to provide up-to-date information about physical assets on the blockchain. As discussed earlier, these could be IoT-enabled monitoring devices, government institutions, various online sources or consensus-based data, among others. At the same time, one of the experts interviewed for this paper expressed his skepticism of the feasibility of using IoT devices to provide reliable data, at least in the current state of the technology. There are still challenges around the installation, operation and maintenance of these devices and how to interpret the data generated.

51% ATTACK

A "51% attack" refers to an attack vector on blockchains with a proof-of-work consensus mechanism. If a certain group acquires more computing power than the rest of the network combined, it can reverse past transactions, while in control, and prevent new ones from being confirmed on the blockchain.

All of the tokenization initiatives reviewed for this paper are currently based on the Ethereum blockchain, or have plans to be, and will tokenize assets using the ERC20 token standard. At the same time, many of them also stress that their protocols are designed to be blockchain agnostic, meaning that they are interoperable among different smart contract platforms. This is particularly important, as technology is evolving at a rapid pace, and today's frontrunners might not be tomorrow's winners.

The Ethereum blockchain is currently the biggest smart contract platform, having the most developers and decentralized applications. During its relatively short life of three years, the platform has certainly had some notable achievements, but also a few failures, such as the DAO hack[4]. Arguably the biggest fundamental changes to the platform, such as changing the consensus protocol from proof of work to proof of stake, are still to be implemented.

> This explains why institutional investors are still hesitant to fully trust the reliability of the Ethereum blockchain, as, at the end of the day, it is a work-in-progress product with a short track record.

Building this trust is essential for tokenizing infrastructure projects, which can have a value of several hundred million dollars each. Otherwise investors will not be comfortable owning these assets on the blockchain at scale.

[4] The "DAO" was a decentralized autonomous organization on the Ethereum blockchain. Its main purpose was to operate similar to a venture capital fund, where investors can vote on proposals to fund. Due to a security vulnerability, an unknown attacker started to drain the USD 150 million worth of ether held by the DAO. In order to prevent the attacker from having access to the funds, the Ethereum community decided to hard fork the Ethereum blockchain, bringing into question the immutability of the network.

Christoph Jentzsch, an early Ethereum developer, highlighted an important limitation of the Ethereum blockchain during the OECD's Blockchain Policy Forum in Paris in September 2018: the Ethereum blockchain cannot hold more value than about 50 per cent of its total market capitalization, which currently is around USD 23 billion (CoinMarketCap, n.d.). So tokenizing something with a higher value would completely shift the centres for a "51% attack" (OECD Blockchain Policy Forum, n.d.). The reason behind the value limitation is that, at this level of valuation, incentives would change and potentially break the game theory behind Ethereum mining. At the same time, it is important to note that if the Ethereum blockchain was about to reach USD 10 billion worth of tokenized securities, then it is very likely that its market capitalization would have increased significantly as well.

One technical challenge that all blockchain-based solutions are currently struggling with is how to create a user experience that is streamlined and easy for the everyday user. Indeed, this is one of the prerequisites of the mass adoption of this technology. If security tokens are also targeting retail investors, they should not be more complicated to use than existing crowdfunding websites or online brokerage accounts. Ultimately, users do not need to understand the underlying technology, the same way most people do not understand how Transmission Control Protocol (TCP) and Internet Protocol (IP) work when they use the Internet. The industry is aware of this problem, and there are many platforms and mobile applications in development that promise significant improvement to user experience.

4

Tokenizing Real Assets: Examples from Switzerland

This section examines theory in practice, discussing several start-up initiatives in Switzerland that are working on solutions for security tokens and the tokenization of real assets.

4.1 Tokenestate

Tokenestate enables companies and real estate asset managers to issue and efficiently manage blockchain-based digital securities through its platform. It provides a complete set of services to issuers by (Tokenestate, 2018b):

- Providing advisory services on security tokens
- Facilitating fundraising in compliance with securities regulations
- Providing a secondary market for security tokens
- Assisting with KYC and AML compliance
- Enabling the efficient management of a large number of investors through digitizing key investment processes such as compliance with prospectus exemptions, pre-emption rights or casting votes during the general assembly

4.1.1 TOKENESTATE.IO

An important component of the Tokenestate ecosystem is the Tokenestate.io. It is a for-profit marketplace that provides various services for launching real estate investment vehicles. It is intended to be the gateway between the existing off-chain real estate funds and the emerging on-chain economy. Tokenestate.io decreases transaction costs significantly for issuers by spreading

many of the one-time costs associated with security token offerings across the different real estate projects.

Tokenestate (2018a) has also developed their own concept of how real estate tokenization could work in a legally compliant manner. A special purpose vehicle called the Token Estate Investment Vehicle needs to be created, which will issue real estate tokens. The Token Estate Investment Vehicle would be the legal owner of a portfolio of real estate projects and would be responsible for the operation of the underlying assets. Its role would be similar to traditional REITs, making decisions on property acquisition or divestment and ensuring compliance with applicable regulation.

4.1.2 THE TOKENESTATE SECURITY TOKEN BLOCKCHAIN STANDARD

Tokenestate has also developed their own proposal for a security token blockchain standard (Trouche, Jolivalt, & Said, 2018). It outlines a typology of functions and proposes a list of common security token functions.

Among other things, Tokenestate argues that security token transactions cannot be immutable and proposes the use of dynamic libraries, which enable the reversal of transactions if needed. The standard also acknowledges that security tokens would need to rely on off-chain and on-chain architectures at the same time.

The off-chain database would be responsible for storing relevant information for regulatory compliance such as KYC and AML. This would include the personal data of investors, data on past transactions and payments of dividends. This off-chain database would be compliant with the recent General Data Protection Regulation in the European Union, allowing personal data to be deleted on request.

The on-chain architecture would include smart contracts and their historical data, all of which would be publicly available and auditable. The standard also argues for the use of public permissionless blockchains for security tokens as opposed to private blockchains. It also emphasizes the importance of being blockchain agnostic (i.e., not committing to any particular blockchain as there are several promising smart contract blockchain ecosystems under development).

In order to see a wider adoption of this technology, there is a need for security token standards that market participants can rely on when tokenizing infrastructure.

Tokenestate executed the first digital share transaction in October 2018, becoming one of the first companies to offer a legally compliant and user-friendly solution for managing the shares of companies and paving the way for the digitization of securities (Trouche, 2018).

4.1.3 RELEVANCE FOR THE TOKENIZATION OF SUSTAINABLE INFRASTRUCTURE

Infrastructure has very similar properties to those of real estate, therefore the solutions proposed by Tokenestate can be easily applied to the tokenization of infrastructure assets. The approach taken by Tokenestate also confirms that there is indeed a need to have an off-chain component when tokenizing real assets. Until financial regulations are designed specifically to fit a blockchain-based market, it would not be possible to have a purely on-chain vehicle. The marketplace proposed by Tokenestate can further decrease the costs associated with tokenization and fulfill a similar function to existing crowdfunding platforms.

In order to see a wider adoption of this technology, there is a need for security token standards that market participants can rely on when tokenizing infrastructure. Indeed, if every platform and issuer needs to reinvent the wheel when issuing security tokens, the tokenization of real assets will not get far.

As infrastructure-backed tokens would be classified as securities, it would be good to see pilots using the security token standard proposed by Tokenestate. A pilot will also demonstrate how much the efficiency gains from tokenization will be retained when the security tokens are issued in a legally compliant manner, relying on several off-chain components. Also, the fact that security token transactions need to be reversible goes against one of the main value propositions of blockchain: immutability. This is indeed the new reality for asset-backed tokens in order to be regulatory compliant and to ensure consistency between the off-chain and on-chain assets.

4.2 Smart Valor

Smart Valor is a Swiss-based company with a mission to democratize access to wealth (Smart Valor, 2018). It recently launched its VALOR Platform, a decentralized marketplace for tokenized alternative investments, such as venture capital, private equity, hedge funds, real estate and commodities. This USD 7 trillion multi-asset class is currently only accessible for high-net-worth individuals and institutional investors. Through the VALOR Platform, anybody will be able to invest in these assets.

The tokens of the following asset types will be traded on the VALOR Platform:

- Traditional infrastructure: renewable energy, transport, utility
- Blockchain infrastructure: protocols, decentralized infrastructure, crypto mining
- Blockchain start-ups: equity tokens
- Currencies: cryptocurrencies, stablecoins
- Non-fungible assets: art, crypto collectibles
- Funds: private equity, venture capital
- Commodities: diamonds, gold
- Intangible assets: intellectual property rights, patents

Smart Valor offers comprehensive services to both investors and token issuers.

For investors:

- Secure and compliant access to new digital assets to diversify portfolios and improve performance
- Portfolio management tools and indexing
- Access to safe-haven wealth protection by providing custody solutions in Switzerland and access to alternative assets with low price volatility

For issuers:

- All the infrastructure needed for tokenization
- Creation of a secondary market with 24/7 liquidity
- Client on-boarding, KYC and AML, assistance with setting up compliant legal entities and structures
- Crypto asset custody solutions
- Banking services such as bank accounts and payments

Smart Valor has already received regulatory approval in Switzerland and Liechtenstein to operate

Regulated market participants and reliable financial infrastructure are essential for institutional investors to enter the space.

as a crypto–fiat exchange. Additionally, they submitted an application to become a bank and an organized trading facility in Liechtenstein in October 2018.

4.2.1 RELEVANCE FOR THE TOKENIZATION OF SUSTAINABLE INFRASTRUCTURE

As tokenized infrastructure is considered to be a security, there is a pressing need for exchanges that are fully regulatory compliant for security token trading. Currently there are only a few of them, which is also the reason why the tokenization of real assets has not gained much traction yet. That is why the efforts of Smart Valor are so important. Regulated market participants and reliable financial infrastructure are essential for institutional investors to enter the space. These market participants include regulated custody providers, financial intermediaries and other regulatory-compliant financial service providers for digital assets.

Smart Valor provides essential services for the tokenization of infrastructure way beyond offering a trading platform. Indeed, token issuers need to have a comprehensive set of solutions to navigate through the various regulatory requirements and technical challenges of tokenization. Trusted partners, like Smart Valor, play a crucial role in giving early adopters confidence in this technology. This is especially important in the case of infrastructure, where deal sizes can easily be in the millions of U.S. dollars.

The success of Smart Valor and similar platforms will also depend on the Swiss regulators, who need to be able to provide clear guidance on how to fit this new asset class into the existing regulatory frameworks and have a supportive approach to finding solutions as needed.

4.3 Mt Pelerin

Mt Pelerin is in the process of becoming a fully regulated and compliant blockchain-based bank. It will tokenize its entire balance sheet: assets, liabilities and equity. It has also developed its own open source security token standard.

Mt Pelerin will have the following unique features:

- All deposits will be kept in a highly liquid reserve in a transparent manner on the blockchain. In contrast, traditional banks only have a small part of client deposits readily available, making them vulnerable to bank runs.
- All banking services will be offered using a marketplace approach. Mt Pelerin will act as a market maker and connect customers and third-party financial service providers. It will be an open platform with easy third-party integration for micro-services. Its revenues will come from the commissions charged for its services and transactions on its marketplace.

4.3.1 SECURITY TOKEN STANDARD

Mt Pelerin is also a pioneer in security tokenization. In October 2018, it became the first company to issue its shares on a blockchain (Mt Pelerin, 2018a). As opposed to past attempts by other companies, the shareholder rights of Mt Pelerin token holders are fully protected by Swiss law. After passing all the KYC and AML checks, token holders will have the right to vote in Mt Pelerin's general assembly and be entitled to receive dividends.

The legal basis for this issuance was the *Blueprint for the Tokenization of Shares of Swiss Corporations* published by the Capital Markets and Technology Association (2018), in which Mt Pelerin Group holds membership. On the blockchain side, the Mt Pelerin Bridge Protocol was used to issue the security tokens. This engine has all the on-chain functionalities to issue tokens and ensure legal compliance throughout the life cycle of the token. It not only enables the tokenization of the shares of Mt Pelerin, but also its entire balance sheet, including debt and multi-currency cash balances.

The Bridge Protocol currently has the following functionality (Mt Pelerin, 2018b):

- Several methods of voting without the use of cumbersome proxy tokens
- Seizing of assets upon court ruling
- Conditional restriction of transferability
- Conditional rights to vote and to receive dividends
- Full support for KYC compliance and whitelisting

The Bridge Protocol is completely open source, and other market participants are encouraged to use it for their own token issuance. Mt Pelerin's goal is that the protocol becomes the de facto Swiss standard for security token issues.

4.3.2 RELEVANCE FOR THE TOKENIZATION OF SUSTAINABLE INFRASTRUCTURE

Security tokens standards are needed to show market participants how to have regulatory-compliant security token offerings (STOs). Standards can decrease transaction costs for issuers and provide legal certainty for token holders. The approach of Mt Pelerin provides an elegant solution to some of the fundamental regulatory and technical challenges faced by issuers. By making the code open source on Github,[5] Mt Pelerin's contribution can potentially have far-reaching impacts if it gains wider adoption.

The list of parameters of the Bridge Protocol demonstrates very well what functionality all security tokens, including tokenized infrastructure, must have to ensure that token holders are treated the same way as traditional shareholders. Regulators need to have the ability to freeze and seize assets if needed. This includes the possibility to reverse transactions. Token holders need to have the right to vote, receive dividends and their ownership of the underlying entity needs to be recognized in court.

It is also encouraging to see that the standard had its first successful pilot, tokenizing the shares of Mt Pelerin. It is important to highlight that Mt Pelerin first issued traditional shares that were tokenized, instead of issuing only tokens. This additional step was needed to be complaint with securities regulations. The next milestone for Mt Pelerin will be the tokenization of the other parts of its balance sheet, namely the assets (loans) and liabilities (deposits). This will be particularly important for infrastructure tokenization, as usually 70 per cent of project financing is in the form of debt (i.e., loans or bonds).

Mt Pelerin has an ambitious goal to become the first fully blockchain-based bank. Its success would be highly beneficial to the whole space, including to the tokenization of infrastructure. Crypto- and blockchain-related projects have had many difficulties opening accounts with traditional banks in Switzerland in the past. Many of these companies had to approach more crypto-friendly financial institutions in Lichtenstein instead. This has certainly limited innovation and the adoption of digital-asset-based solutions in Switzerland. Mt Pelerin could be the perfect gateway to bridge the blockchain space with the financial sector.

[5] Find the open-source code at https://github.com/MtPelerin/MtPelerin-protocol

4.4 SwissRealCoin – Crypto Real Estate Ltd

SwissRealCoin (SRC) is a security token linked to a portfolio of Swiss commercial real estate. SRC is issued by Crypto Real Estate Ltd, whose focus is to automate real estate asset management (SRC, 2018a).

The SRC token will have the following unique structure (SRC, 2018b):

- Under Swiss law, SRC tokens will be a perpetual subordinated non-interest bearing bond. Proceeds will be used to fund Crypto Real Estate Ltd and the acquisition of the real estate portfolio: 92 per cent of the proceeds will be invested in Swiss commercial real estate; 5 per cent will be used by Crypto Real Estate Ltd to develop its real estate management software "MIA"; and the remaining 3 per cent will cover various operating expenses.
- Investments will be potentially leveraged by using bank loans, which will be ranked more senior than the SRC tokens. In addition, the underlying real estate assets might be used as collateral for these loans.
- SRC will be an ERC20 using the Ethereum blockchain. Investors will be able to buy it either at the primary issuance or when the token gets listed on a security-token-compliant exchange.
- 80 per cent of the net rental income and 50 per cent of net profit from the IP licensing of the MIA software will be re-invested in further real estate projects.
- SRC token holders will have voting rights, making decisions on the acquisition of new assets and on the liquidation of the portfolio. For the latter, 80 per cent of the majority will be needed initially, which will decrease by 2 per cent with every completed year.
- SRC will have a built-in mechanism to decrease the price volatility of the token. If the price of SRC exceeds the value of the underlying real estate portfolio by two times, a smart contract issues additional SRC tokens to purchase more real estate. In case the price of SRC falls below the value of the portfolio, token holders could exercise their option to liquidate the entire portfolio. This would limit downside price volatility.

The security token offering is expected to take place at the end of 2018 with a hard cap of CHF 150 million (maximum amount) and a soft cap of CHF 30 million (minimum amount).

Besides the unique characteristics above, SRC offers investors a significant improvement in transparency compared to existing real estate investment vehicles, high-quality data from operations and material efficiency gains throughout the investment process.

4.4.1 RELEVANCE FOR THE TOKENIZATION OF SUSTAINABLE INFRASTRUCTURE

While SRC's underlying portfolio is commercial real estate, the proposed token structure could be easily applied to any infrastructure portfolio due to the similar characteristics of the two asset classes.

Crypto Real Estate Ltd. has taken a very different approach to tokenizing real assets than the previous examples. SRC tokens will represent subordinated bonds of the real estate portfolio instead of equity. Subordinated bonds rank below senior debt but higher than equity in the case of a claim on assets or earnings. These bonds will be perpetual (no maturity to return the principal) and non-interest bearing (no coupon payments) but will give voting rights to token holders. In many ways, they are very similar to equities, except they do not give token holders ownership rights of the issuing entity nor the right to receive dividends. Indeed, this is a very important difference that token holders should evaluate carefully.

Why would you tokenize subordinated debt instead of equity? One reason could be that the legal entity owning the real estate assets has other commercial activities, so token holders cannot have a claim over the entire business of the issuer. Or it could be simply that there are no security token

standards for regulatory-compliant tokenized equity in the jurisdiction of the issuing entity. This also highlights the significance of the Mt Pelerin and Tokenestate standards in Switzerland.

> Cryptocurrencies and other tokens have been criticized for being too volatile for more conservative institutional investors. It is to be seen whether this volatility persists in the case of asset-backed tokens.

SRC presents an interesting solution to mitigating its price volatility. The fact that investors can ask for the liquidation of the fund, subject to voting and initial lock up, can certainly create a floor for any persistent price decline of the SRC token. On the other hand, new SRC tokens are issued when the market capitalization of SRC becomes twice as much as the NAV of the portfolio. It is an innovative way to ensure that valuation of the tokens stays in line with the underlying real estate portfolio.

It is yet to be seen whether other tokenization solutions for real assets integrate similar price stabilizing mechanisms. That will certainly depend on investor preference. At the end of the day, there is often a significant difference between the stock valuations of listed companies and their respective book values.

The fact that the public sale has been postponed highlights some of the challenges similar structures might also experience. First, SRC will be a security token, which requires a specific setup to be regulatory compliant, as discussed previously. Second, as a whole portfolio will be tokenized, the issuing entity also needs to comply with the Collective Investment Scheme Act, as it is structured similarly to off-chain investment funds. As more of these funds reach successful close, it will become easier for new entrants. Regulators will also gain more understanding of the blockchain space, become more comfortable granting the necessary licences and develop new internal procedures to deal with tokenized real assets.

5 Conclusion

The main value proposition of tokenization lies in its potential to decrease the cost of financing of infrastructure projects. Better terms of long-term financing can tip the balance toward financial viability for projects that either had to remain on the drawing board or relied on some form of de-risking solutions, often using public resources, to become bankable. Despite the range of potential benefits, the question remains whether tokenization will have widespread adoption for infrastructure in the coming years. Market participants need to have complete trust in the underlying technology and certainty about the regulatory and legal compliance of these new financial instruments. Building this trust will take time and require many successful pilot projects.

Could IoT devices indeed deliver on their promise to generate a wide range of operational data on site? How could this data be used on the blockchain?

Blockchain has several use cases for infrastructure beyond financing that could be explored in more detail. For example, one area to be unpacked further is how blockchain could bring transparency to the asset class and what it would mean for the different stakeholders involved. Could IoT devices indeed deliver on their promise to generate a wide range of operational data on site? How could this data be used on the blockchain? What are the opportunities and risks of assessing the environmental and social footprints of projects in real time? Indeed, having a large amount of reliable data opens up a range of possibilities for all stakeholders, including project sponsors, investors, governments and local communities.

Another pressing question is how the benefits and challenges of tokenization would differ in the developing country context. While the use case for blockchain-based solutions is the most apparent

in these countries, they also tend to be the most restrictive when it comes to regulating the space. One of the key risks of investing in infrastructure in developing countries is political risk. For example, in the case of capital restrictions, profits denominated in local currency might be impossible to repatriate for international investors. Blockchain technology can also enable the fast and frictionless movement of capital into infrastructure projects, which otherwise would not be possible to achieve. What about countries with hyperinflation? Could cryptocurrencies be used to make payments linked to the operations of the project, thus eliminating the need to access hard currencies?

Can this new technology fit into existing regulatory frameworks?

On the regulatory side, there are also several outstanding questions. There is still a lack of clarity from regulators on how tokenized real assets can be fully regulatory compliant. Can this new technology fit into existing regulatory frameworks? For example, how can you regulate or take enforcement action against a decentralized exchange, which is not operated by a centralized entity? How do you comply with the EU's General Data Protection Regulation, requiring operators to offer the possibility to delete client's data on request, when a blockchain is immutable? How do you transfer securities on-chain between counterparties when transactions often require a signature by law? Of course, there are solutions or workarounds for every problem. However, it is yet to be seen how much the benefits of blockchain will be lost in the process of complying with regulations clearly designed for an off-chain world.

The recently emerged ICO funding model is already undergoing a major transformation. During 2017 and the first half of 2018, we have seen a wave of ICOs raising billions of dollars from mostly retail investors. However, when regulators signalled that ICOs might be unauthorized security offerings, new issuances have come to a halt. By the end of 2018, start-ups had the choice of either approaching traditional venture capital investors or experimenting with security token offerings. It is important to note that many STOs to date have only been available to qualified accredited investors, which again limits the access to these investments to high-net-worth individuals and institutional investors. Does this suggest that once digital assets are fully regulatory compliant, the democratization of finance will yet again become far out of reach? Will utility tokens still be distributed through ICOs or rather through some form of airdrops?

Whether blockchain will deliver on all the expected benefits proponents claim, and indeed will play a role in creating a more inclusive financial system, is yet to be seen. However, this technology is here to stay, and it will be disruptive. As with the Internet in the 1990s, how fast market participants integrate this "trust machine" into the financing and operation of infrastructure will affect their competitiveness for years to come.

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Annex 1. Key Concepts

Most people have already heard about blockchain and initial coin offerings, either due to the meteoric rise of cryptocurrencies in 2017 or due to the ambitious promise of this new technology to transform businesses, financial services and many aspects of our society. At the same time, many people lack a high-level understanding of how the technology works and what some of the key concepts mean.

The purpose of this section is to provide a brief description of the more technical blockchain-related terms used throughout the paper.

51% ATTACK

"51% attack" refers to an attack vector on blockchains with a proof-of-work consensus mechanism. If a certain group acquires more computing power than the rest of the network combined, it can reverse past transactions, while in control, and prevent new ones from being confirmed on the blockchain.

For example, in the case of Bitcoin, the cost of such an attack would be huge, while potential benefits quite uncertain. Therefore it is not considered to be the most likely attack vector. If the goal of the malicious actor is not to double spend but to disrupt the network, distributed denial of service attacks are a much more cost efficient way to do so (van Valkenburgh, 2018).

AIRDROPS

In the blockchain context, airdrops refer to the free distribution of tokens to community members. A good analogy would be customers of an airline receiving miles, which can be later used for additional services within the same ecosystem.

Blockchain start-ups usually use airdrops as a promotional activity to raise awareness and to bootstrap their projects. Also, airdrops can be used to reward existing customers, similar to vouchers and other commercial discounts in the traditional world. As some of the airdrops require recipients to register, it could also serve as a way to build client databases, enabling more targeted marketing (Katalyse.io, 2018). Airdrops can also play an important role in creating a network effect by expanding the number of participants in the ecosystem. If more people own the token then there is potentially more liquidity and use of the network.

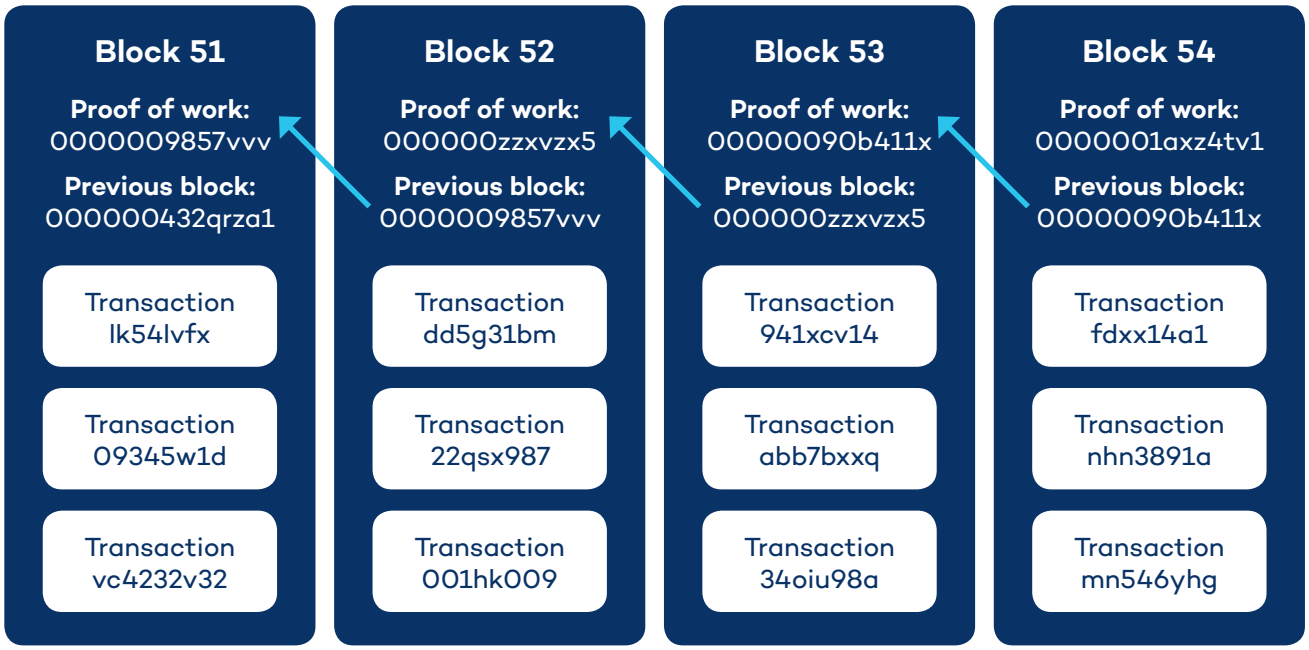
For example, Stellar, the sixth biggest cryptocurrency based on market capitalization, has given away a majority of their 100 billion tokens created. Fifty per cent of the tokens were distributed to individuals who registered with an invitation link; 25 per cent of the tokens were given away to partners of Stellar; and 20 per cent were given to bitcoin and XRP (another cryptocurrency) holders (Stellar, n.d.).

In 2018 we saw increased airdrop activity as a way to distribute tokens instead of the usual ICO model. The reason behind this is that regulators have signalled that many of the ICOs could be considered unauthorized security offerings. Airdrops are one way to ensure that the tokens are not considered to be securities, as they do not raise funding from recipients.

BLOCKCHAIN

Blockchain is a peer-to-peer distributed ledger technology invented by Satoshi Nakamoto in 2009 to serve as the public transaction ledger for the cryptocurrency bitcoin. It allows the transfer and storage of data without relying on a third party. Each block contains a set of transactions, which are linked using cryptography. Once information is confirmed by the network, it cannot be altered without the consensus of the network and without changing all the subsequent blocks.

Figure A1 . Blockchain



Valid transactions are put into blocks by the nodes, also called miners. Each block has a unique cryptographic hash, which is essentially a string of digits. Even the slightest change in the block will result in a completely different hash. The header of the proposed block includes this unique hash along with some other data. The hash of the header becomes the new block's identifying string, and that block is now part of the ledger, as illustrated in Figure A1 (The Economist, 2015a).

It is also important to distinguish between public permissionless, public permissioned and private blockchains.

On a permissionless blockchain, anybody can become a node (i.e., a network validator), create a wallet on the blockchain and send transactions. There is no centralized entity operating the network or having the power to change the underling protocol or shut down the system. All transactions processed by the network are visible to the public. Most cryptocurrencies, like bitcoin, operate on a permissionless public blockchain.

For a public permissioned blockchain, there is a centralized entity or selected entities that have the power to grant permissions to perform specific functions on the blockchain, such as validating transactions. As it is a public blockchain, transactions are transparent and can be seen through the relevant blockchain explorer. For example, XRP of Ripple, a cryptocurrency, is operating on a public permissioned blockchain.

Private permissioned blockchains are usually set up for a specific purpose and are controlled by a single entity. They are often used by companies who want to take advantage of the blockchain technology to streamline their internal processes. Often there is no mining involved. If a particular use case requires high confidentiality, transaction throughput and immediate finality, then private permissioned blockchains are probably the best solution (Kolisko, 2018). Hyperledger Fabric from the Linux Foundation is a popular private blockchain framework.

CONSENSUS MECHANISM

Consensus mechanism is the process by which nodes agree on which transactions are valid. In other words, it determines how decisions are made on the network. There are several different consensus mechanisms available. Proof of work and variations of proof of stake are currently the most popular of them.

- **Proof of Work:** The purpose of this algorithm is to prevent cyberattacks on the system by being time consuming and resource intensive to produce, but easy to verify. It also enables a distributed and trustless consensus. It is an important component of "mining," which is the process of verifying the legitimacy of transactions and creating new digital currencies as a reward for the "miners." Bitcoin and many of the leading cryptocurrencies use proof of work (Blockgeeks, n.d.).
- **Proof of Stake:** The purpose of this algorithm is the same as for proof of work, but how it achieves this goal is different. In a proof of stake system, the creator of the next block is selected in a deterministic way, such as size of holdings, as opposed to solving complex mathematical puzzles. There are no digital currencies created through mining, and validators receive only the transaction fees. This means that all the coins that will ever be available are created in the beginning. Some of the newer cryptocurrencies (e.g. NEO, Lisk, Cardano) use proof of stake.

ERC20 TOKEN

ERC20 is a token protocol standard on the Ethereum blockchain. It describes the functions and rules that an Ethereum-based token has to implement (The Ethereum Wiki, 2018). This is by far the most popular token standard used by initial coin offerings. ERC20 tokens can be traded the same way as any other cryptocurrency or token. The main difference is that they do not have their own dedicated blockchain, but instead they use Ethereum's. The ERC20 token standard offers the following benefits (Khatwani, 2018):

- Uniform protocol standard
- Reduced complexity of token implementation
- Enhanced liquidity
- Lower risk of breaking contracts

At the time of writing, there are more than 130,000 different ERC20 token contracts on the Ethereum blockchain (Etherscan, n.d.).

HARD AND SOFT FORKS

Hard and soft forks are permanent changes in the underlying protocol layer of the blockchain. They could either add new functionality or change a core rule in the protocol. Using Microsoft Windows as an analogy, soft fork would be a security patch, while hard fork would be a new version of Windows.

Soft fork is similar to a backward-compatible software upgrade. It does not require all nodes to upgrade to reach consensus, but blocks produced based on the old set of consensus rules have a chance to become stale (i.e., get discarded and do not become part of the blockchain).

Hard fork, on the other hand, is major non-backward compatible upgrade of the underlying protocol. In order to continue validating transactions, nodes need to upgrade to the new version. If there is continued mining support of the old version then the blockchain may fork (i.e., both versions continue to exist at the same time).

In the case of planned hard forks, developers have consensus beforehand, so there is usually only a single blockchain continued after the upgrade. On the other hand, for contentious hard forks there is usually a significant disagreement between groups of developers on what upgrades will result in a superior blockchain. One notable example is the Bitcoin Cash fork, where proponents of Bitcoin Cash advocated for a block size increase of Bitcoin, while the majority of developers wanted to scale Bitcoin in different ways (Asolo, 2018). This resulted in two separate blockchains, each having its own set of developers and miners: Bitcoin (BTC) and Bitcoin Cash (BCH).

> "I believe every ICO I've seen is a security."
>
> Securities and Exchange Commission chairman Jay Clayton at a U.S. Senate hearing on cryptocurrencies in February 2018 (Higgins, 2018)

INITIAL COIN OFFERING/SECURITY TOKEN OFFERING

Initial coin offering (ICO) was initially a new way of crowdfunding blockchain-based applications and start-ups. As a tokenholder, one could benefit from the success of the platform or service through the price appreciation of the token but would not have ownership rights or receive dividends. Since regulators signalled that many of the ICOs were actually unauthorized security offerings (Higgins, 2018), this funding model has evolved significantly. Now ICOs are only used for cryptocurrencies and utility tokens, while STOs are used for raising venture-capital-type funding from eligible investors.

Under both the ICO and STO models, investors receive a predetermined number of newly issued crypto tokens in exchange for bitcoin, Ethereum or fiat currencies. Unlike venture capital, these tokens are usually tradable not long after issuance, once listed on an exchange, providing an efficient secondary market for investors.

INTERNET OF THINGS (IoT)

Internet of Things is a concept of connecting any devices to the Internet and to each other. This also includes connecting different components of devices, such as sensors of an airplane, and even people. This giant network of connected things will be able to communicate and exchange data with each other (Morgan, 2014). For infrastructure projects, IoT devices can be sensors and other appliances monitoring the operating performance of the asset.

SMART CONTRACTS

Smart contracts are computer programs intended to verify or implement a contract. They execute a pre-defined set of terms automatically in a trackable and irreversible manner without the need for a third party (Tar, 2017). The idea was originally described by Nick Szabo, a cryptographer, using a vending machine as an example: a specific set of input generates a predefined output. While it is possible to have basic smart contracts on the Bitcoin blockchain, they only gained real traction with the emergence of Ethereum. This blockchain platform enabled the creation and implementation of complex smart contracts and contributed significantly to the popularity of smart-contract-based decentralized applications (Dapps).

TOKEN TYPES

Financial regulators are working on a clear set of rules for categorizing digital tokens. The objective is to help issuers understand what the applicable regulations are for their tokens and how to do regulatory-compliant new issues. Currently these categories vary across jurisdictions. FINMA, the Swiss Financial Market Supervisory Authority, categorizes tokens into three groups based on their economic functions and purposes (FINMA, 2018):

- **Payment tokens:** cryptocurrencies without any other functions or links to development projects
- **Utility tokens:** tokens providing digital access to an application or service
- **Asset tokens:** tokens representing assets such as participation in real physical underlyings, companies, or earnings streams, or an entitlement to dividends or interest payments. Asset tokens are analogous to equities, bonds or derivatives. They are also called security tokens.

It is possible to have hybrid forms, where tokens belong to more than one category. Based on this categorization, all tokenized infrastructure would be treated as an asset token, requiring issuers to comply with relevant securities law and civil law requirements.

TOKENIZATION

Bankex (2018) defines tokenization as the "process of transferring the information and associated values of real-world assets onto the blockchain." In other words, tokenization is the digitalization of real-world assets. It is similar to securitization in financial markets as it also transforms an illiquid asset into a tradable security, or in this case, a token. It also allows for fractional ownership, as each token represents a small part of the underlying asset. In theory, any type of asset can be tokenized as long as there is a process in place to ensure consistency between the on-chain token and the off-chain asset.

For the purposes of this paper, infrastructure tokenization refers to the tokenization of the equity of the special purpose vehicle owning the infrastructure. Even if it will become possible to tokenize one square metre of a building, this approach would not make sense for the type of solutions we seek to explore in this paper. As infrastructure is mostly financed by debt, usually 70 per cent, project debt tokenization is certainly worth considering. The first blockchain-based bond was recently issued by the World Bank, raising AUS 110 million (World Bank, 2018).

With the use of smart contracts, the characteristics of traditional financing instruments, such as equity and bonds, can be mixed and combined as needed. Consequently, tokenization can enable another level of financial engineering, where different hybrid instruments can be designed to suit the specific needs of the project. For example, currently it is not possible to have voting rights for traditional bonds, while for tokenized bonds, it would just be adding another smart contract to the token.

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