

Infrastructure Tokenization

Does blockchain have a role in
the financing of infrastructure?



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Enabling Infrastructure Investment



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¹ Mt Pelerin is a financial intermediary duly affiliated with VQF, a Self-Regulatory Organization (SRO) officially recognized by Switzerland's Federal Financial Market Supervisory Authority (FINMA). The group specializes in financing solutions using blockchain. They seek to create an ecosystem that will propel the new era of financial digitalization that blockchain facilitates.

Sygnum is the world's first digital asset bank and a digital asset specialist with global reach. The bank is independently controlled, scalable and future-proof digital asset banking solution.

Fasset is a platform for the ethical financing of sustainable infrastructure. The platform leverages modern blockchain technology to allow infrastructure owners (governments, utilities, public-private partnerships, etc.) to securely offer asset-backed investments to institutional investors, including sovereign wealth funds, government-linked investment funds, infrastructure funds, private equity funds, real estate funds, and banks.

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** All currency in this publication is in U.S. dollars unless otherwise noted.*

Executive Summary

The purpose of this report is to assess whether digitizing the equity or debt financing used for infrastructure projects using blockchain, i.e., tokenized infrastructure, provides enough benefits to justify the use of this technology. The information presented here aims to inform the World Bank whether it should explore the possibility of tokenizing one of its infrastructure projects. The conclusions are based on interviews with tokenization start-ups, experts, and the review of current and planned regulatory frameworks in selected jurisdictions and use cases/pilots to date.

Financing of infrastructure using blockchain technology: tokenization of assets

Infrastructure investment is a means to generate long-term benefits to society with inclusive economic growth and well-being while contributing to a low-carbon transition.² However, the sector is faced with several challenges including poor governance and management of infrastructure systems.³ Projects are also often large, capital intensive, and not immediately profitable.⁴ Therefore, innovative mechanisms are required to leverage private financing and lower the costs of capital. It is also crucial to maintain information symmetry amongst stakeholders and provide investors with transparent data to make informed investment decisions. One of the foremost impediments is matching abundant supply of private capital to the demand for infrastructure.⁵

The use of distributed ledger technologies (DLT) like blockchain can potentially overcome many of the challenges that hinder the scaling of infrastructure. The efficiency of financing and management of infrastructure projects can improve by leveraging core features of the technology like decentralization, immutability, and transparency.^{6,7} The blockchain is an immutable technological infrastructure designed to enable simultaneous access, validation, and record updating spread across several networks.⁸ These features make blockchain a disruptive technology capable of transforming businesses. The most common application of this technology in finance could be capital-raising through Security Token Offerings (STOs), and in post-trade processes, like clearing and settlement of securities.

Another application of blockchain technology is the tokenization of real assets. Tokenization is the process of converting rights, a unit of asset ownership, debt, or even a physical asset into a digital token on a blockchain.⁹ This enables historically illiquid assets to be broken down into smaller units representing ownership and encouraging the democratization of finance.

² <https://www.oecd.org/gov/infrastructure-governance/resilience-maintenance/>

³ <https://sdg.iisd.org/news/world-bank-report-illustrates-benefits-of-resilient-infrastructure/>

⁴ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

⁶ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

⁷ <https://www.frontiersin.org/articles/10.3389/fbloc.2019.00016/full>

⁸ <https://www.investopedia.com/terms/d/distributed-ledger-technology-dlt.asp>

⁹ <https://www.bnymellon.com/us/en/insights/all-insights/tokenization-opening-illiquid-assets-to-investors.html>

The potential advantages of tokenizing “real-world” assets include: efficiency gains driven by automation and disintermediation, transparency, and greater liquidity and tradability of illiquid assets. The tokenization of assets can democratize the ownership of certain assets as a wider range of investors have access. As opposed to blockchain native tokens, like bitcoin, that only have value on the blockchain, real-world assets have an underlying value off-chain as well, backed by the real assets existing outside the ledger. The most prominent use of tokenization of real-world assets are securities (bonds and stocks), commodities (like gold), and non-financial assets (like real estate).

The tokenization of infrastructure is claimed to address three objectives: financing initiatives,¹⁰ democratizing infrastructure,¹¹ and increasing the efficiency of infrastructure management.¹² These objectives are interconnected and enabled through the core features of blockchain technology—decentralization, immutability, and transparency. The data derived from infrastructure use and performance results can uncover operational inefficiencies as well as unlock new revenue streams for third-party planning on building new services and capital appreciation opportunities.¹³

The following are some specific activities related to infrastructure development that blockchain technology can improve:

1. Improved project management
 - Contractual standardization
 - Financial standardization
 - Project preparation
 - Bridging data gap

2. Improved investment environment
 - Financial engineering, risk allocation, and mitigation
 - Regulatory frameworks and capital markets
 - Quality infrastructure

The use of smart contracts in infrastructure projects:

Infrastructure management is often complicated, involving several contractors and subcontractors. Contractors are usually entrusted with the responsibility to submit the correct subcontract amounts. However, contractors often overstate the amount driven by the vested interest of increasing the mark-up chargeable by the vendor. Overstating amounts can occur as incorrect recordings of the sub-amount or application of tax, union fees, or other statutory charges. Manual effort is then required to verify and rectify these amounts, which is both cost and time intensive.

¹⁰ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

¹¹ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

¹² <https://www.interaxis.io/blog/real-world-assets-defi/>

¹³ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

The use of smart contracts¹⁴ can improve the transparency of the process by verifying invoices and linking them to master data in real-time blockchain database. The report proposes a three-way match of the invoice for implementation:

- a. Purchase order/ Scope of work: This contains the list of activities contracted to subcontractors by a major contractor/owner representative. The invoice should match and reflect these activities approved by the contractor/owner representative.
- b. Certified progress: This contains activities completed by the subcontractor and certified by the supervisor designated by the major contractor. This progress should match and be appropriately demonstrated as completed.
- c. Master data: This contains the basis of the invoice consisting of the rate list (for each activity), activity code list, mark-up list, and acceptable operations ratios. For instance, operator cost to equipment cost, overhead cost to labor cost, and logistic cost to overall cost.

This three-way matching with the invoice validates the contractual details entered by contractors and ensures the costs and operational ratios are set within the established parameters. Blockchain enables transactions to contain all aspects of the contract and invoices while tracking any change to the scope of work and progress on the master data. Any change to the contract or invoice will be visible to the owner, the prime contractor, and subcontractor simultaneously.

This way of smart contracting also curbs the risk of non-compliance by contractors. The embedding of pre-determined operating ratios for each activity optimizes the process by triggering an alert to all the stakeholders—the owner, main contractor, and subcontractor in the event of non-compliance. This enhanced transparency will reduce cases of non-compliant spending and highlight inefficiencies along the supply chain. Based on this assessment, companies can reallocate resources towards activities that will facilitate higher-quality subcontractor work. Furthermore, an automated process enables real-time resolution of changes to orders and claims reducing ambiguities and potential mistakes.

Smart contracts enable the programming and auto-execution of various operating scenarios to transparently verify invoices as per the terms of the contract. This increases transparency in contract administration and reduces the need for a full-time contract administrator.

To summarize, tokenization has the potential to transform infrastructure financing as we know it. It could democratize access to markets while ensuring fairness and security. However, there are several obstacles including legal and regulatory challenges that hinder the scaling of the technology and question its applicability.

¹⁴ Smart contracts are used to execute automated transactions on the blockchain when one or more preconditions are met. Simple programs can be stored on the blockchain, for instance, medical records, E-notary, and collecting taxes. Smart contracts increase efficiency of transactions by eliminating the need for intermediaries and third parties.

Tokenization of infrastructure – Risks and Considerations

Despite the potential advantages associated with infrastructure tokenization, the process is legally and technically complicated, which is hindering the adoption of blockchain technology. While in traditional securities each individual asset type is subject to local regulations, tokenization enables automated compliance with tokens being traded. This can raise new concerns such as overuse of computational infrastructure, speculative arbitrage because of unclear regulatory frameworks for issuance and compliance enforcement, and community participation in overcoming potential privacy infringement issues. The following are the most prominent risks associated with asset tokenization, which need to be carefully considered as the key challenges are regulatory rather than technologically related:

- **Tokenizing different security types:** Infrastructure tokens can represent a variety of security types and ownership interests, including the ownership *of an* infrastructure asset, an equity interest in the company owning the asset, a debt position secured by the asset, or the revenue stream generated by the asset. The nature of the security being tokenized determines the regulation applying to the token. At the same time, security regulations can differ and are often inconsistent across jurisdictions. This raises the question whether infrastructure tokenization can democratize the asset class, or it would only target the usual private equity/debt investors.
- **Lack of legal clarity and governance risks:** The lack of a globally recognized code of conduct/tokenization standard for managing digital assets remains the greatest challenge to decentralized technology. The lack of a globally acceptable standard prevents legal clarity on key provisions relating to claiming ownership rights, integration of anti-money laundering and know-your-customer (AML/KYC) requirements, admin rights, and integration with secondary markets are not considered. The problem of technology evolving much faster than regulations prevents the “borderless nature of blockchain” from truly achieving its potential.
- **Legal status of digital tokens:** Tokenized securities have to comply with legal regulations like conventional securities law. Only a few jurisdictions recognize tokens as digital assets. The tokenization of assets enables the creation of a holding vehicle for the purchase of loans and other assets. The shares of this vehicle are then sold to participating investors providing diversification and reducing the risk of ownership. Like traditional special-purpose vehicles (SPVs), tokens must also represent a legal entity that owns the infrastructure project(s). However, most jurisdictions around the world do not recognize infrastructure tokens to represent an independent investment, questioning the legal status of infrastructure tokens. These tokens can be traded either through a decentralized exchange (DEX) or by listing them on eligible crypto exchanges providing secondary market liquidity for an otherwise illiquid asset class. Additionally, virtual tokens are subject to more stringent regulations in comparison to regular securities.
- **Legal status of smart contracts:** Smart contracts are the core of many blockchain applications. They implement pre-established unchangeable agreements programmed on the blockchain without requiring human intervention. These contracts execute instructions like receiving dividends. Despite its critical importance, there is no jurisdiction that provides a legal definition for smart contracts. Experts have identified few obstacles to providing smart contracts with a legal

status—first, the need to maintain technological neutrality in regulations; and secondly, the multiple standards and functionalities available for specific codes and blockchains. As a result, the legal status of smart contracts is yet to be defined in many jurisdictions, resulting in a lack of enforceability and giving rise to consumer protection concerns.

- **Cyber security concerns:** The use of smart contracts also raises major cybersecurity concerns. The characteristic features like automation and immutability increase its vulnerability to cyber hacks and expose investors to fraudulent practices. To ensure cyber security, it is important for tokens to comply with AML/KYC. It is critical to maintain accountability of ownership of tokens that would require collaboration with security token exchanges to track ownership. This compliance requires expert supervision and subsequently increases the costs to an issuer.

Examples of conducive regulatory frameworks for implementing tokenization of infrastructure

The use of blockchain technology has the potential to disrupt how infrastructure is currently being financed if there is an enabling regulatory environment. Countries with a strong legal framework for DLT-based securities present an attractive destination for issuing these security tokens and participating in the token economy. The following are a few leading examples

- **United States:** As an emerging technological solution, the tokenization of infrastructure is subject to different laws at the federal and state levels. In 2019, 28 states introduced legislation for blockchain, with 27 bills and resolutions enacted and adopted. In September 2020, the Office of the Comptroller of the Currency (OCC) allowed national banks to provide permissible banking services to any lawful business they choose, including cryptocurrency businesses as long as they effectively manage the risks and comply with applicable law including those relating to the AML and Bank Secrecy Act (BSA) provisions.
- **Luxembourg:** Luxembourg is currently one of the most conducive jurisdictions for infrastructure tokenization. Its legal framework is designed to enable the benefits of blockchain that are the most relevant and beneficial for the country, such as using blockchain to eliminate intermediaries in the asset management industry.
- **Liechtenstein:** Liechtenstein developed a holistic regulatory framework dedicated to the token economy. In January 2020, Liechtenstein became the first country with comprehensive regulatory guidelines under the Blockchain Act or Token and Trusted Technology Service Provider Act, the Gesetz über Token und VT-Dienstleister 54/2019 of Liechtenstein.
- **Switzerland:** In 2020, Switzerland passed the Distributed Ledger Technology (DLT) Act enabling innovation using ledger-based technologies. Unlike in the case of Liechtenstein, this DLT act is not a self-contained law but is a blanket act modifying existent civil law (in respect of securities), financial market infrastructure law (DLT trading facility), the Banking Act, and bankruptcy regulations. A key feature of the act is the formal recognition of uncertified registered securities or digital securities that can be transferred without financial intermediaries. This provides legal certainty on the ownership and transfer of those tokens.
- **France:** France was one of the first countries to provide a legal standing for blockchain and to allow the use of the technology for registration and transfer of securities. The “Blockchain Order”

was introduced in 2017, a regulatory framework established in French law to govern the representation and transmission of unlisted financial securities via DLTs. In 2019, the Plan d'Action pour la Croissance et la Transformation des Entreprises, also known as the Loi Pacte (the “Pacte Law”), was enacted in France to foster entrepreneurship and innovation, facilitating the growth of businesses and creating jobs. The law is said to govern blockchain applications and provide guidance to crypto asset service providers (CASPs) on the issuance and management of DLT related services.

- **European Union (EU):** As a part of the EU Digital Finance Package in 2020, the European Commission published the draft Regulation for Markets in Crypto Assets (MiCA) to foster innovation and competition in digital finance while controlling associated risks. Largely inspired by the French PACTE Law of 2019, the regulation intends to regulate players in crypto markets rather than the assets themselves. The regulation will apply to any person issuing crypto assets, or associated services. However, will not apply to security tokens that are already subject to existing EU regulatory regimes.

Applicability to emerging markets

Emerging markets and developing economies (EMDEs) currently lag behind in both the resources required for developing pilots, as well as regulatory frameworks for governing projects. However, the tokenization of infrastructure has the potential to positively impact EMDEs the most. The financing of infrastructure in EMDEs is faced with government deficits, issues of transparency and insufficient financial efficiency, as well as the lack of performance tracking, which tokenization can address.

Tokenization in developing countries can elevate private sector confidence via improving infrastructure asset liquidity, while opening access to small-scale projects and enlarging participation in infrastructure development. EMDE governments can benefit from prospective administrative and financial efficiencies brought about by automated auditing, enhanced project monitoring, and lower financing costs. Small-scale projects often deliver the most economic and social impact per dollar spent. However, these projects face barriers to financing due to high transaction costs due to their small size. By tokenizing small scale infrastructure projects, due-diligence and transaction costs can be decreased significantly. Taken together, tokenization has the impact to transform both the economies and people’s lives in EMDEs.¹⁵ However, to unlock the complete benefits of blockchain through tokenization, it is important to carefully examine and overcome the potential risks and barriers in EMDEs through:

- a. **Regulatory harmonization:** For mainstream adoption through a global user base, STO regulation of different jurisdictions needs to be harmonized. In the EMDE context, policymakers need to update the legal and regulatory frameworks to address the opportunities and risks associated with tokenization. Establishing the legal status of asset-backed tokens and smart contracts must be prioritized. Taxation policies should be modernized, such that asset tokens are aligned for tax purposes. A careful balance of regulation should be maintained to ensure the market is both

¹⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

secure and favorable for the private sector to participate in. Experts have proposed multilateral development banks (MDBs) with other nongovernmental organizations initiate a working group to develop a process to test “low-hanging fruit” applications towards more broadly defined infrastructure investment domains.¹⁶ A hybrid globalized governance and reporting system to integrate the specific tokenization requirements of target countries can be established to create global alignment of smart contracts.¹⁷

- b. **Pilot testing and sandboxes:** There is a need for developing pilots and regulatory sandboxes for promising-use cases to gain practical insights and test the advantages and constraints in a real-world setting.¹⁸ To test and learn about the technology, some jurisdictions like South Africa and the Philippines¹⁹ have already established regulatory sandboxes to allow for a more flexible approach in consultation with the regulator. Sandboxes create a safe space in which businesses can test innovative products, services, business models, and delivery mechanisms in a live environment without immediately incurring all the normal regulatory consequences.²⁰
- c. **Capacity building:** Tokenization is a novel concept using a nascent technology. It requires capacity building of decision and policymakers to facilitate the development of regulatory frameworks.²¹ National governments and international organizations like the World Bank can work with researchers and industry practitioners to establish case studies for specific countries to assess the local opportunities and risks associated with tokenization.

Conclusions and main takeaways

Blockchain technology has the potential to deliver a wide range of benefits through its ability to enforce trust in a trustless environment. The exponential growth of cryptocurrencies and tokens demonstrates there is an increasing acceptance of this new asset class, and the benefits of this technology are more and more recognized among financial market participants. At the same time, it is important to make the distinction between crypto as an asset class and tokenized securities. In the case of the latter, which is the focus of this paper, blockchain only serves as a digital vehicle or technological enabler. A tokenized equity or tokenized debt have similar financial characteristics and are regulated the same way as their traditional “off-chain” equivalents.

Regulation, or rather the lack of regulation designed for tokenized securities, is the main barrier of using blockchain for the financing of infrastructure. The extent to which national security regulations accommodate tokenization can vary significantly across jurisdictions. As pointed out earlier, while there has been some notable progress in a few countries, there is still a lot of work to be done on the regulatory front before the full potential of tokenized securities can be realized.

¹⁶ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹⁷ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹⁸ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹⁹ <https://www.bakermckenzie.com/>

/media/files/insight/publications/2020/05/a_guide_to_regulatory_fintech_sandboxes_internationally_8734.pdf?la=en

²⁰ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

²¹ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

Another challenge is how tokenization can deliver on its value proposition to democratize finance, while complying with securities regulation. Indeed, it has the potential to provide access to a wider range of investors, including retail, to asset classes that were traditionally off limits. Investors seeking to have exposure to infrastructure normally have to become limited partners (LPs) in private equity or debt funds. However, due to their large minimum ticket sizes (over \$1 million), these funds are only a viable option for high-net-worth individuals (HNWI) or institutional investors.

Tokenization can decrease these minimum sizes significantly, while making these investments more liquid. At the same time, many of the infrastructure tokenization projects to date were only accessible for accredited investors due to securities regulation. While the requirements differ across jurisdictions, generally becoming an accredited investor is not a possibility for retail investors. This is another area where financial regulation needs to evolve to better accommodate this new technology—otherwise tokenization cannot fulfil its promise to democratize investments.

In light of this, should the World Bank further explore infrastructure tokenization? The World Bank should consider tokenizing one of its infrastructure projects if it wants to pursue any of the following objectives:

- Drive change in financial regulation to better accommodate the use of security tokens
- Demonstrate leadership in the use of blockchain technology
- Interact with the crypto economy

When the World Bank issued the world's first green bond in 2008, the issuance has probably cost more than the traditional alternative. However, that transaction created the blueprint for today's sustainable bond market that has grown exponentially over the years, reaching \$1 trillion issuance in 2021 alone.²² That green bond defined what should be the eligibility criteria for the use of proceeds and what to include in an impact report. It also provided a new model on how different stakeholders, such as investors, development finance institutions (DFIs), and scientists, could collaborate on a new bond issue. It also formed the basis for the ICMA Green Bond Principles that is still being used to this day by the large majority of green bond issuances.²³

This is where the opportunity lies also in the context of infrastructure tokenization. The decision whether the World Bank should explore this technological solution further should not be made based on the expected short-term benefits of a pilot. Instead, the question is what the Bank's long-term aspirations are in paving the way for the wider use of blockchain technology in the financing of infrastructure.

²² https://assets.website-files.com/5df9172583d7eec04960799a/61786e26cde36b7570c6ae62_bx9570_Q3%20SF%20report_26Oct2021.pdf

²³ <https://www.worldbank.org/en/news/immersive-story/2019/03/18/10-years-of-green-bonds-creating-the-blueprint-for-sustainability-across-capital-markets>

1. Financing of infrastructure using blockchain technology

Blockchain technology has come a long way since it was first conceptualized with the creation of the Bitcoin network in 2008. The number of cryptocurrencies and other tokens using the technology have increased exponentially in recent years, reaching 14,000²⁴ in 2021. This growth has also been reflected in valuations: the total market capitalization of crypto assets is approaching \$2.9 trillion, based on the listings on CoinMarketCap.²⁵ While the blockchain's value proposition of immutability has a range of use cases that goes beyond the transfer of value, it has been mainly used to date in a financial context. This does not only include cryptocurrencies and utility tokens, but also decentralized finance (DeFi) solutions that enable the provision of financial services, such as lending, without an intermediary.

At the same time, the use of asset-backed tokens, where real world assets are digitized, have been limited to date. This might be surprising when considering the list of benefits that blockchain could offer in this area, including increased liquidity, access to a larger capital pool and better transparency. There are some notable challenges that held back the wider adaption of these tokens that will be discussed in more detail later.

A comprehensive report was published on infrastructure tokenization²⁶ in early 2019, where IISD discussed the value proposition of blockchain for the financing of infrastructure projects, and also covered a range of start-ups trying to tackle the digitalization of real assets. We will build on the findings of that report and reflect on how the space has evolved in the meantime and discuss the future of infrastructure tokenization going forward.

The purpose of this report is to assess whether digitizing the equity or debt financing used for infrastructure projects using blockchain, (i.e., tokenize infrastructure), provides enough benefits to justify the use of this technology. The information presented here aims to inform the World Bank whether it should explore the possibility of tokenizing one of its infrastructure projects. Our conclusions will be based on interviews with tokenization start-ups, our in-house expertise, the review of current and planned regulatory frameworks in selected jurisdictions and use cases/pilots to date.

Due to the limited literature and pilots available for infrastructure tokenization, we will use real estate tokenization as a proxy where appropriate.

The World Bank's blockchain-based bond

The World Bank is certainly not new to the use of blockchain technology. It issued the world's first bond on the blockchain in 2018.²⁷ This "Global Blockchain Bond", also called "bond-1", is fully managed using

²⁴ <https://coinmarketcap.com/>

²⁵ <https://coinmarketcap.com/charts/>

²⁶ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

²⁷ <https://www.worldbank.org/en/news/press-release/2018/08/23/world-bank-prices-first-global-blockchain-bond-raising-a110-million>

distributed ledger technology (DLT) throughout its lifecycle. Investors showed strong interest for the \$110 million AUD issue, including some well-known organizations such as the Treasury Corporation of Victoria, QBE, and Northern Trust. “We welcome the huge interest that this transaction has generated from various stakeholders and will continue to seek ways to leverage emerging technologies to make capital markets more secure and efficient,” said Arunma Oteh, World Bank Treasurer, underlying the significant demand from investors.²⁸

The bond came out of the World Bank’s ITS Technology & Innovation Lab, designed to understand the use of blockchain in development financing. It is using a private Ethereum-based blockchain of the Commonwealth Bank of Australia’s (CBA) Blockchain Centre of Excellence. This blockchain is operated by the World Bank and CBA in Washington, D.C., and Sydney, respectively.

The World Bank issued a second tranche of \$50 million AUD in 2019, demonstrating the platform’s ability to accommodate the needs of issuers throughout the entire bond life cycle.²⁹ This innovative bond issuance was generally well received in the wider blockchain space. For example, Matthew Di Ferrante, who previously worked for the Ethereum Foundation, said, “I think it's a good first example. Financial instruments like bonds are easily ported to blockchains/smart contracts, but it's not the be-all and end-all even for mainstream financial institutions. The real usefulness will come when many different institutions and industries are all using interoperable blockchains.”³⁰ Indeed, if capital markets are to tap the full potential of this technology, bond issues should share the same blockchain, creating a common marketplace, instead of each bond issue using their own segregated platform.

Another notable limitation of private blockchains is the lack of decentralization, which is normally a key value proposition of the technology. This was also echoed by Di Ferrante in the case of the World Bank’s bond-I: “It's good to see that at least in this case, it seems that the system CBA has set up will be co-managed by the World Bank, giving it some decentralization, but I'd like to see more transparent, more distributed projects even for private blockchains.”³¹

As the World Bank’s interest in the tokenization of infrastructure also demonstrates, it continues to explore the uses of blockchain technology in development finance.

²⁸ <https://fortune.com/2018/08/24/world-bank-blockchain-bond/>

²⁹ <https://www.worldbank.org/en/news/press-release/2019/08/16/world-bank-issues-second-tranche-of-blockchain-bond-via-bond-i>

³⁰ <https://cointelegraph.com/news/world-banks-blockchain-based-bonds-a-step-toward-adoption>

³¹ <https://cointelegraph.com/news/world-banks-blockchain-based-bonds-a-step-toward-adoption>

2. Scaling infrastructure: Value proposition of blockchain technology

Infrastructure investment is a means to generate long-term benefits to society with inclusive economic growth and well-being while contributing to a low-carbon transition.³² However, the sector is faced with several challenges including poor governance and management of infrastructure systems.³³ Projects are also often large, capital intensive, and not immediately profitable³⁴ Therefore, innovative mechanisms are required to leverage private financing and lower the costs of capital. It is also crucial to maintain information symmetry amongst stakeholders and provide investors with transparent data to make informed investment decisions. One of the foremost impediments is matching abundant supply of private capital to the demand for infrastructure.³⁵

The use of DLT, like blockchain, can potentially overcome many of the challenges that hinder the scaling of infrastructure, especially those pertaining to transparency and fractional ownership. The efficiency of financing and management of infrastructure projects can improve by leveraging core features of the technology like decentralization, immutability, and transparency.^{36,37} The blockchain is an immutable technological infrastructure designed to enable simultaneous access, validation, and record updating spread across several networks.³⁸ These features make blockchain a disruptive technology capable of transforming businesses. The most common application of this technology in finance is capital-raising through Initial Coin Offerings (ICOs) or Security Token Offerings (STOs), and in post-trade processes, like clearing and settlement of securities.³⁹

Distributed Ledger Technology:

Distributed Ledger Technology (DLT) is an immutable technological infrastructure designed to enable simultaneous access, validation, and record keeping. The network can be spread across multiple locations and entities simultaneously.

Blockchain:

³² <https://www.oecd.org/gov/infrastructure-governance/resilience-maintenance/>

³³ <https://sdg.iisd.org/news/world-bank-report-illustrates-benefits-of-resilient-infrastructure/>

³⁴ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

³⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

³⁶ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

³⁷ <https://www.frontiersin.org/articles/10.3389/fbloc.2019.00016/full>

³⁸ <https://www.investopedia.com/terms/d/distributed-ledger-technology-dlt.asp>

³⁹ <https://www.oecd.org/finance/The-Tokenisation-of-Assets-and-Potential-Implications-for-Financial-Markets.pdf>

Blockchain is a type of DLT used for record keeping and transfer of value without requiring a trusted entity to maintain a database and validate transactions. Instead, a decentralized network containing the data accomplishes through an immutable single source. This “single source of truth” is transparent and accessible by all participants. The technology is tamper-proof through a process called “consensus,” which ensures that each transaction is independently verified by multiple parties. Each entry is immutable, or can only be updated by adding an addendum. Blockchains can either have a public network where anyone can join at any given point and participate in the consensus process, or private, where only a single organization has authority over the network.⁴⁰

The main value proposition of blockchain is ensuring data integrity and improving efficiency. There are several blockchain-based applications building on these features including cryptocurrencies, crowdfunding, tracking of goods in the supply chain, and authentication.⁴¹ Some of the most popular blockchain applications have proven to be useful in streamlining the management of data in various sectors, such as finance, healthcare, education, entertainment, retail, and e-commerce.⁴² Cross-sectoral applications include digital cash transfers at ultra-low rates without intermediaries, personal identity security, anti-money laundering tracking system, voting mechanisms, and advertising insights.⁴³

⁴⁰ <https://101blockchains.com/public-vs-private-blockchain/#:~:text=A%20private%20blockchain%20is%20a,has%20authority%20over%20the%20network.&text=Basically%2C%20private%20blockchain%20solutions%20develop,trust%20to%20use%20this%20platform.>

⁴¹ <https://www.frontiersin.org/articles/10.3389/fbloc.2019.00016/full>

⁴² <https://consensus.net/blockchain-use-cases/>

⁴³ <https://consensus.net/blockchain-use-cases/>

3. Tokenization of assets

How can tokenization make real-world assets ‘tradable’?

Another application of blockchain technology is the tokenization of real assets. Tokenization is the process of converting rights, a unit of asset ownership, debt, or even a physical asset into a digital token on a blockchain.⁴⁴ This enables historically illiquid assets to be broken down into smaller units representing ownership and encouraging the democratization of finance. Tokenized assets can be of two types— fungible and non-fungible tokens (NFTs). Fungible tokens are divisible and interchangeable, where each unit of the asset has the same market value and validity, for instance, bitcoin.⁴⁵ The second type of tokenized assets, NFTs are unique, indivisible, and transferable. NFTs have gained a lot of attention recently, with a total transaction value exceeding \$10 billion,⁴⁶ by tokenizing digital art, music, and network domains.⁴⁷

Tokenization:⁴⁸

Tokenization is the process of representing a fungible asset (like infrastructure) or nonfungible asset (like art) as a digital token that can be stored and tracked on a blockchain. The token is interchangeable with other items of same value if it is fungible and transferable in ownership if it is non-fungible. Tokenization facilitates the sharing and ownership of unique assets.

Tokens:⁴⁹

Tokens or digitalized assets do not have their own blockchains but live on other blockchains. Tokens can represent both fungible and non-fungible assets, containing metadata like ownership, provenance, certification, and history of processes.

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

⁴⁴ <https://www.bnymellon.com/us/en/insights/all-insights/tokenization-opening-illiquid-assets-to-investors.html>

⁴⁵ <https://hedera.com/learning/what-is-asset->

[tokenization?gclid=CjwKCAiAm7OMBhAQEiwArvGi3NTz2Vqj_DdN5K27C9U__uik3zMprTa8JrYOVTR-67_ZKtprxR442xoC2mUQAvD_BwE](https://www.bnymellon.com/us/en/insights/all-insights/tokenization-opening-illiquid-assets-to-investors.html)

⁴⁶ <https://www.cnbc.com/2021/10/16/what-are-nfts-heres-what-you-need-to-know-about-non-fungible-tokens.html>

⁴⁷ <https://www.cnbc.com/2021/10/16/what-are-nfts-heres-what-you-need-to-know-about-non-fungible-tokens.html>

⁴⁸ <https://globacap.com/content-hub/learn/what-is-tokenization/>

⁴⁹ <https://www.iisd.org/publications/tokenization-infrastructure-blockchain-based-solution-financing-sustainable>

- Utility tokens: tokens providing digital access to an application or service
- Asset tokens: tokens representing assets such as participation in real physical underlying, 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

The potential advantages of tokenizing “real-world” assets include: efficiency gains driven by automation and disintermediation, transparency, and greater liquidity and tradability of illiquid assets.⁵⁰ The tokenization of assets can democratize the ownership of certain assets as a wider range of investors have access. As opposed to blockchain native tokens like bitcoin that only have value on the blockchain, real-world assets have an underlying value off-chain as well, backed by the real assets existing outside the ledger. The most prominent uses of tokenization of real-world assets are securities (bonds and stocks), commodities (like gold), and non-financial assets (like real estate).⁵¹

Security tokens and tokenized securities:⁵²

While tokens represent blockchain-native tokens that do not exist outside of the blockchain, tokenized securities are blockchain-embedded representations of real-world assets. While security tokens have imitated traditional securities, there is potential for disruption. Traditional security can achieve additional positive or negative features by being represented by a token such as automated payments.

Potential advantages of blockchain to address the challenges of financing infrastructure

Infrastructure is an evolving asset class,⁵³ and a key driver of economic growth and prosperity. The G20 has recognized the role of infrastructure in enhancing job creation, productivity, and eventually growth. The sector can generate employment opportunities on on-site construction as well as construction-related professional services and the supply of materials and components.⁵⁴ Infrastructure can also be built in the pursuit of goals other than growth, for instance, to promote social equity, environmental preservation, public health, and political goals.⁵⁵

⁵⁰ <https://www.oecd.org/finance/The-Tokenisation-of-Assets-and-Potential-Implications-for-Financial-Markets.pdf>

⁵¹ <https://www.oecd.org/finance/The-Tokenisation-of-Assets-and-Potential-Implications-for-Financial-Markets.pdf>

⁵² <https://deliverypdf.ssrn.com/delivery.php?ID=241124005024106087114023000117014066007003009040033092067067109077117029028087027102114017055054029044016126103018087126119018008000007082048024120091084016068081074061093077021126097093019092070110017111072115102096019100117004074001080104028000082021&EXT=pdf&INDEX=TRUE>

⁵³ https://www.statestreet.com/content/dam/statestreet/documents/Articles/YoungIlliquidIrresistible_v2.pdf

⁵⁴ https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_416378.pdf

⁵⁵ <https://documents1.worldbank.org/curated/en/189471550755819133/pdf/134795-vol-1-33256cmp-eProof-rev.pdf>

However, there is an immense gap in infrastructure investment in both developed and emerging economies. As reported by the OECD,⁵⁶ the estimates of the gap vary based on the methodology used, for instance, the McKinsey Global Institute estimates a cumulative infrastructure gap of \$5.5 trillion between 2018 and 2035. On the other hand, the Global Infrastructure Hub estimates a cumulative gap of \$15 trillion between 2018 and 2040. In 2019 the hub estimated expenditure of between \$3 trillion and \$5 trillion per year to keep with the vast demand for infrastructure.⁵⁷ As a result, there is a perennial challenge of maintaining resources for existing and future infrastructure projects.

Given the vast size and heterogeneous nature of infrastructure assets, the projects face several challenges. The main challenges of infrastructure and commercial real estate including an opaque policy environment, large upfront investments, low short-term liquidity, and high management costs, which make tokenization an attractive option.^{58,59} Only a few investors will commit to bear long-term exposures to meet their long-term liabilities. Furthermore, there is a lack of critical mass of bankable projects and often insufficient data to track the performance of the asset.

The tokenization of infrastructure is claimed to address three objectives: financing initiatives,⁶⁰ democratizing infrastructure,⁶¹ and increasing the efficiency of infrastructure management.⁶² These objectives are interconnected and enabled through the core features of blockchain technology: decentralization, immutability, and transparency. The data derived from infrastructure use and performance results can uncover operational inefficiencies as well as unlock new revenue streams for third-party planning on building new services and capital appreciation opportunities.⁶³ The following are some specific activities related to infrastructure development that blockchain technology can improve:

1. Improved project management

- Contractual standardization
- Financial standardization
- Project preparation
- Bridging data gap
- Faster payments and real-time tracking
- Reduced M&E expenses resulting from real-time audits

2. Improved investment environment

⁵⁶ https://www.oecd.org/g20/roadmap_to_infrastructure_as_an_asset_class_argentina_presidency_1_0.pdf

⁵⁷ <https://documents1.worldbank.org/curated/en/189471550755819133/pdf/134795-vol-1-33256cmp-eProof-rev.pdf>

⁵⁸ <https://deliverypdf.ssrn.com/delivery.php?ID=241124005024106087114023000117014066007003009040033092067067109077117029028087027102114017055054029044016126103018087126119018008000007082048024120091084016068081074061093077021126097093019092070110017111072115102096019100117004074001080104028000082021&EXT=pdf&INDEX=TRUE>

⁵⁹ <https://www.interaxis.io/blog/real-world-assets-defi/>

⁶⁰ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

⁶¹ https://www.oecd-ilibrary.org/environment/blockchain-technologies-as-a-digital-enabler-for-sustainable-infrastructure_0ec26947-en

⁶² <https://www.interaxis.io/blog/real-world-assets-defi/>

⁶³ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

- Financial engineering, risk allocation, and mitigation
- Regulatory frameworks and capital markets
- Quality infrastructure

Demonstration of the use of smart contracts in infrastructure projects

Smart contracts:

Smart contracts are used to execute automated transactions on the blockchain when one or more preconditions are met. Simple programs can be stored on the blockchain, for instance, medical records, E-notary, and collecting taxes. Smart contracts increase efficiency of transactions by eliminating the need for intermediaries and third parties.

Process of tokenizing infrastructure⁶⁴

The first step in the tokenization of infrastructure is to price and audit the underlying assets. Smart contracts are then generated to address the various requirements, aligned with the appropriate regulations. Once the legal and deal structures for asset tokenization are established, key actors in the transaction are selected. These include: asset token (security token) issuance service provider, anti-money laundering and know-your-customer (AML/KYC) vendor, and custodian and primary/secondary marketplaces.⁶⁵ The management of special-purpose vehicles (SPVs) set the prices and calculate values for asset tokens. Potential investors will have to pass the AML/KYC requirements to gain accreditation before investing. On the completion of these processes, newly minted tokens are transferred to wallets of accredited investors or get listed on public exchanges. Tokens can then be transferred or traded amongst accredited investors on the secondary market. The dividends and interest payouts generated from these tokenized assets are directly sent to the wallets of the token owners in the form of cryptocurrency or equivalent fiat currency.

Steps for infrastructure tokenization:

1. Origination	2. Digitalization	3. Distribution	4. Exchange	5. Post-tokenization management
<ul style="list-style-type: none"> • Due Diligence • Design deal structure 	<ul style="list-style-type: none"> • Appraise infrastructure assets 	<ul style="list-style-type: none"> • Evaluate investors • AML/KYC • Price tokens 	<ul style="list-style-type: none"> • Manage whitelist 	<ul style="list-style-type: none"> • Distribute dividend • Enable shareholder voting

⁶⁴ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

⁶⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

<ul style="list-style-type: none"> • Determine the terms and conditions of the digital token backed by infrastructure assets • Code legal and regulatory requirements into smart contracts • File documents 	<ul style="list-style-type: none"> • Establish SPV • Select technology platform selection • Program smart contracts • Transfer transactional information onto the blockchain 	<ul style="list-style-type: none"> • Distribute tokens to primary investors in exchange for investment capital • Store transactional information automatically onto the blockchain without the participation of intermediaries. 	<ul style="list-style-type: none"> • Trade on secondary (token exchange or traditional capital markets) • Peer-to-peer transfer 	<ul style="list-style-type: none"> • Reporting • Taxing • Accounting
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Source: Adapted from Tian et. al (2020).⁶⁶

A report⁶⁷ published by EY in 2018 further demonstrates the effective use of smart contracts in infrastructure construction projects:

Subcontractor management:

Infrastructure management is often complicated, involving several contractors and subcontractors. Contractors are usually entrusted with the responsibility to submit the correct subcontract amounts. However, contractors often overstate the amount driven by the vested interest of increasing the amount mark-up chargeable by the vendor. Overstating amounts can occur as incorrect recordings of the sub-amount or application of tax, union fees, or other statutory charges. Manual effort is then required to verify and rectify these amounts, which is both cost and time intensive.

The use of smart contracts can improve the transparency of the process by verifying invoices and linking them to master data in real-time blockchain database. The report proposes a three-way match of the invoice for implementation:

- a. Purchase order/Scope of work: This contains the list of activities contracted to subcontractors by a major contractor/owner representative. The invoice should match and reflect these activities approved by the contractor/owner representative.
- b. Certified progress: This contains activities completed by the subcontractor and certified by the supervisor designated by the major contractor. This progress should match and be appropriately demonstrated as completed.

⁶⁶ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

⁶⁷ https://assets.ey.com/content/dam/ey-sites/ey-com/en_ca/topics/blockchain/ey-how-blockchain-can-enable-smarter-contracts-in-infrastructure.pdf?download

- c. Master data: This contains the basis of the invoice consisting of the rate list (for each activity), activity code list, mark-up list and acceptable operations ratios. For instance, operator cost to equipment cost, overhead cost to labor cost, logistic cost to overall cost.

This three-way matching with the invoice validates the contractual details entered by contractors and ensures that the costs and operational ratios are set within the established parameters. Blockchain enables transactions to contain all aspects of the contract and invoices while tracking any change to the scope of work and progress on the master data. Any change to the contract or invoice will be visible to the owner, the prime contractor, and subcontractor simultaneously.

This way of smart contracting also curbs the risk of non-compliance by contractors. The embedding of pre-determined operating ratios for each activity optimizes the process by triggering an alert to all the stakeholders—the owner, main contractor, and subcontractor in the event of non-compliance. This enhanced transparency will reduce cases of non-compliant spending and highlight inefficiencies along the supply chain. Based on this assessment, companies can reallocate resources towards activities that will facilitate higher-quality subcontractor work. Furthermore, an automated process enables real-time resolution of changes to orders and claims reducing ambiguities and potential mistakes.

Public-private partnership (PPP) operations:

Contract administration for long-term operations is a time-consuming process requiring the administrator to verify each invoice with the operations log and scope of services outlined in the contract. EY⁶⁸ proposes to program a smart contract to govern and execute all these operational agreements as per appropriate operating scenarios. For instance, the clause on service-level agreements (SLAs) would provide guidelines for expected performance of certain capital, like elevators, throughout the life of the contract.

Smart contracts enable the programming and auto-execution of various operating scenarios to transparently verify invoices as per the terms of the contract. This increases transparency in contract administration and reduces the need for a full-time contract administrator.

From these examples, the following could be the key advantages to tokenizing infrastructure over traditional infrastructure financing:

a. Enhanced liquidity and alternative sources of capital

The tokenization of infrastructure increases liquidity and opens the market to more investors and wider pools of capital. It enables the creation of secondary markets and eliminates steep liquidity premiums priced by lenders and investors of the market, which could reach up to 60% of the net asset value.⁶⁹ Access

⁶⁸ https://assets.ey.com/content/dam/ey-sites/ey-com/en_ca/topics/blockchain/ey-how-blockchain-can-enable-smarter-contracts-in-infrastructure.pdf?download

⁶⁹ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

to cheap financing is one of the main barriers challenging small-scale infrastructure, despite their ability to deliver most economic and social impact per dollar spent.⁷⁰ Tokenizing small-scale infrastructure makes it a more attractive investment due to greater liquidity, shorter lock-in periods, and lower transaction costs and project management expenses. Therefore, tokenization can not only benefit the infrastructure asset class, but also real estate. Real estate is the single largest asset class roughly \$228 trillion in total assets—but only less than 1% can be traded on a national exchange due to its illiquid nature.⁷¹ At present, only 7% of all commercial real estate is available to investors, however, the capital flowing into crowdfunding sites prove that over 80% of individuals seek investment opportunities in real estate.⁷²

b. Efficiency gains

The tokenization of infrastructure enables technological automation of issuance and post-issuance to reduce investment ticket sizes. This increases the liquidity of the asset and subsequent investor base and capital pool. As a result, investors are subject to shorter lock-in periods. The traditional limits on fractional ownership are eliminated, increasing the participation of more investors. Furthermore, blockchains are global in nature and can be accessed by anyone having an internet connection. Most importantly, the use of smart contracts eliminates intermediaries and additional administrative costs associated with the transaction process. As demonstrated in the previous section, the use of blockchain technology can increase the efficiency of several processes linked to contracts by eliminating third-party involvement. For instance, the completion of work, delivery of materials, and transfer of payments to contractors and subcontractors can be encoded and automated through blockchain. This can reduce the commercial disputes and lack of coordination between various stakeholders involved in a project.

c. Fair pricing and lower transaction costs

Tokenization eliminates financial, legal, and regulatory intermediaries, potentially reducing costs related to the public listing and secondary market transactions. Depending upon the size and location of the property, going public can cost up to 22% of the property value.⁷³ In contrast, the overall fee for tokenization could be well below 5% of the property value.⁷⁴ On the secondary market, the tokenized assets avoid brokerage commissions for equity transactions costing up to 2% of purchase and sale of real estate investment trusts. Tokenized assets are also exempt from the one-time commission charged on non-listed real estate investment trusts (REITs) reaching up to 15% of the transaction. The avoidance of these expenses reduces the cost of investment significantly, attracting more investors. The use of blockchain also reduces the risk of cross-border currency fluctuations impacting the bankability of projects⁷⁵ However, fluctuations in blockchain transaction costs must be factored in. For instance, the transaction

⁷⁰ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

⁷¹ <https://www.bizjournals.com/houston/news/2021/10/01/tokenization-real-estate-investing-gain-liquidity.html>

⁷² <https://www.bizjournals.com/houston/news/2021/10/01/tokenization-real-estate-investing-gain-liquidity.html>

⁷³ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

⁷⁴ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

⁷⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

costs in public blockchains can fluctuate significantly when there is a supply-demand mismatch leading to nodes prioritizing transactions with higher fees, resulting in users attempting to outbid each other. In the case of private blockchains, the initial deployment can be an estimated USD 1500 per month with its maintenance costing up to 25% of the overall project cost depending on its complexity.⁷⁶ ⁷⁷

d. Transparency and informational symmetry

Blockchain claims to be a “trust machine” with potential to improve the transparency and accountability of infrastructure projects. Transparency offered by blockchain technology increases information symmetry across all stakeholders. Data generated through Internet of Things (IoT) devices enhances the accuracy of the financial modelling of infrastructure projects. Accurate forecasting of key assumptions related to contingency costs, size of liquidity, and working capital facilities can lower costs. Improving the quality and quantity of information available can potentially increase the valuation of an asset during its operating life.⁷⁸

e. Lower counterparty risk

Counterparty risk is one of the main risks in financial transactions. Tokenization of assets does not eliminate counterparty risks as a borrower can still default on its debt obligations. However, decentralization avoids the data breach by any central authority and reduces the risk of a central point of failure. As a result, tokenization eliminates the counterparty risks associated with financial intermediaries that is still present in traditional finance.

To summarize, tokenization has the potential to transform infrastructure financing as we know it. It could democratize access to markets while ensuring fairness and security. However, there are several obstacles including legal and regulatory challenges that hinder the scaling of the technology and question its applicability.

⁷⁶ <https://www.leewayhertz.com/cost-of-blockchain-implementation/>

⁷⁷ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

⁷⁸ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

4. Tokenization of infrastructure —risks and considerations

Despite the potential advantages associated with infrastructure tokenization, the process is legally and technically complicated,⁷⁹ which is hindering the adoption of blockchain technology. While in traditional securities each individual asset type is subject to local regulations, tokenization enables automated compliance with tokens being traded.⁸⁰ This can raise new concerns such as overuse of computational infrastructure, speculative arbitrage as a result of unclear regulatory frameworks for issuance and compliance enforcement, and community participation in overcoming potential privacy infringement issues.⁸¹ The following are the most prominent risks associated with asset tokenization, which need to be carefully considered as the key challenges are regulatory rather than technologically related.

a. Tokenizing different security type

Infrastructure tokens can represent a variety of security types and ownership interests, including the ownership of an infrastructure asset, an equity interest in the company owning the asset, a debt position secured by the asset, or the revenue stream generated by the asset.⁸² The nature of the security being tokenized determines the regulation applying to the token. At the same time, security regulations can differ and are often inconsistent across jurisdictions. For instance, if a token is qualified as equity by the U.S. Securities Exchange Commission and is either held by 2,000 people or 500 non-accredited investors and has over \$10 million in assets, the tokens must be registered.⁸³ On the other hand, tokenized debt is subject to the same regulation as asset-backed securities.

Asset-backed Securities:

Asset-backed securities (ABS) are financial securities backed by income-generating assets allowing issuers to raise cash used for lending/investment purposes.⁸⁴ The underlying assets of an ABS are often illiquid and cannot be sold independently. Pooling assets together and creating a financial instrument out of them is a process called securitization, which makes illiquid assets more marketable to investors.

Many STOs are only available for high-net-worth individuals or “accredited investors,” which dilutes the intended impact of “democratizing infrastructure” by providing retail investors access to the asset class. Sometimes issuers have set a very high minimum investment size for prospective investors. This raises the

⁷⁹ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

⁸⁰ <https://www.oecd.org/daf/fin/financial-markets/Regulatory-Approaches-to-the-Tokenisation-of-Assets.pdf>

⁸¹ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

⁸² <https://www.dlapiper.com/en/us/insights/publications/2019/09/proptech-in-the-united-states-issue-2/>

⁸³ <https://www.sec.gov/info/smallbus/secg/jobs-act-section-12g-small-business-compliance-guide.htm>

⁸⁴ <https://www.investopedia.com/terms/a/asset-backedsecurity.asp>

question whether infrastructure tokenization can democratize the asset class or would only target the usual private equity/debt investors.

b. Lack of legal clarity and governance risks

The lack of a globally recognized code of conduct/tokenization standard for managing digital assets remains the greatest challenge to decentralized technology. The lack of a globally acceptable standard prevents legal clarity on key provisions relating to claiming ownership rights, integration of AML/KYC requirements, admin rights, and integration with secondary markets are not considered. The problem of technology evolving much faster than regulations prevents the “borderless nature of blockchain” from truly achieving its potential.

There are several other complexities involved in the process of tokenization that are currently dealt with on a case-by-case basis. The regulations will also vary depending on the ratio of the property to be tokenized, its location, and the number and class of investors for which the tokenized property is subject to a pre-existing mortgage. In that case, the issuer will need to obtain consent from the mortgagee, and alternatively, if the tokenization is a mortgage itself, then appropriate laws will have to be observed.⁸⁵

Governance risks of fully decentralized ledgers arise from the difficulty in identifying a sole owner/node accountable for the full network.⁸⁶ The lack of a single owner/node makes it difficult to regulate DLT networks and assign responsibility for the failure in the network. Complexities in ownership of relationships of assets underlying asset-backed securities (ABS) make repatriation difficult.⁸⁷ For instance, an ABS can have several owners, whose consent is required for the sale and management of the asset.

The transfer of property rights may vary from one country to another. The tokenization of infrastructure also complicates the legalities surrounding transferability and ownership rights of asset-backed token holders. For instance, while tokens offer investors the possibility to gain fractional ownership with little investment, the codes of smart contracts are held by one company and managed by another only when required.⁸⁸ Token holders do not own the infrastructure, but rather own a “share” of it. Tokenization encodes existing regulations on transfer of property into applicable rules for tokens. Experts have indicated this hybrid form of extrapolating contractual and property rights to smart contracts called “bit-property” to be the end of classic contract law.⁸⁹ Several issues related to tokenization of property rights

⁸⁵ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

⁸⁶ <https://www.ifc.org/wps/wcm/connect/da7da0dd-2068-4728-b846-7cfcfd1fd24a/EMCompass-Note-63-Blockchain-and-Legal-Issues-in-Emerging-Markets.pdf?MOD=AJPERES&CVID=mxocw9F>

⁸⁷ <https://www.ifc.org/wps/wcm/connect/da7da0dd-2068-4728-b846-7cfcfd1fd24a/EMCompass-Note-63-Blockchain-and-Legal-Issues-in-Emerging-Markets.pdf?MOD=AJPERES&CVID=mxocw9F>

⁸⁸ <http://housing.urv.cat/wp-content/uploads/2021/05/WP-1-2021-Digital-tokenization-property-rights.pdf>

⁸⁹ <http://housing.urv.cat/wp-content/uploads/2021/05/WP-1-2021-Digital-tokenization-property-rights.pdf>

and national and EU law dealing with the legal nature of asset-backed tokens, like the admissibility of ICOs and tax issues, are under-researched by academia.⁹⁰

Tax and reporting considerations need to be highlighted as only a few jurisdictions provide guidance on these issues. For instance, in the United States, those issuers relying on a Regulation A+ exemption from registration are required to file regular reports with the SEC after offering.⁹¹ Finally, tokenization does not eliminate the counterparty risk that exists in such transactions. Even if laws like the Swiss DLT law provides protection against counterparty default within Switzerland, it cannot provide protection extraterritorially or if the transaction is done with a foreign entity.

c. Legal status of digital tokens

Tokenized securities have to comply with legal regulations like conventional securities law.⁹² Only a few jurisdictions recognize tokens as digital assets.⁹³ For instance, in 2021, while Liechtenstein and Italy regard tokens as assets, jurisdictions like Switzerland and Germany do not.⁹⁴ Policymakers of several jurisdictions have opted for specific, customized rules for tokenized assets and DLT-enabled markets more broadly, in spite of a technology-neutral approach to financial regulation. These include France, Luxembourg, Malta, Switzerland, and Germany for the issuance of electronic and DLT-based securities.⁹⁵

The tokenization of assets enables the creation of a holding vehicle for the purchase of loans and other assets. The shares of this vehicle are then sold to participating investors providing diversification and reducing the risk of ownership. Like traditional SPVs, tokens must also represent a legal entity that owns the infrastructure project(s).⁹⁶ However, most jurisdictions around the world do not recognize infrastructure tokens to represent an independent investment, questioning the legal status of infrastructure tokens. These tokens can be traded either through a decentralized exchange (DEX) or by listing them on eligible crypto exchanges providing secondary market liquidity for an otherwise illiquid asset class.

⁹⁰ <http://housing.urv.cat/wp-content/uploads/2021/05/WP-1-2021-Digital-tokenization-property-rights.pdf>

⁹¹ <https://www.sec.gov/smallbusiness/exemptofferings/regaf#:~:text=Regulation%20A%20is%20an%20exemption,in%20a%2012%2Dmonth%20period.>

⁹² <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

⁹³ Digital assets tokens can represent any asset or agreement between parties with the potential to either settle directly against digital currency or alternative payment solutions. These tokens enhance market efficiency by enabling end-to-end solutions, combining trading, settlement, and custody services into a single offering. Thereby unlocking liquidity in previously illiquid markets. However, not all assets are legally recognized as “digital assets”..” Every jurisdiction needs to define what assets can be considered as “digital assets”, and hold similar rights as their non-digital counterparts. For instance, property rights, ownership, and transferability.

⁹⁴ <http://housing.urv.cat/wp-content/uploads/2021/05/WP-1-2021-Digital-tokenization-property-rights.pdf>

⁹⁵

https://goingdigital.oecd.org/data/notes/No19_ToolkitNote_AssetTokenisation.pdf?utm_source=Adestra&utm_medium=email&utm_content=Understanding%20the%20tokenisation%20of%20assets%20in%20financial%20markets&utm_campaign=Business%20and%20Finance%20News%20from%20the%20OECD%20-%20November%202021&utm_term=daf

⁹⁶ <https://dilandorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

Additionally, virtual tokens are subject to more stringent regulations in comparison to regular securities. Depending upon the features of the token, a variety of regulations could be applied—for instance, money services law and commodities regulations, general anti-fraud, and consumer-protection laws.⁹⁷ Compliance with these laws is usually costly and time-consuming, diminishing the benefits of the use of blockchain technology.

d. Legal status of smart contracts

Smart contracts are the core of many blockchain applications. They implement pre-established unchangeable agreements programmed on the blockchain without requiring human intervention.⁹⁸ These contracts execute instructions like receiving dividends. However, bugs in smart contracts could be exploited by hackers and potentially result in the theft of the tokens. Due to the immutability of blockchain, these illicit transactions cannot be reversed. Given the high risk involved, technical security audits are mandatory to identify and remedy any flaws in smart contracts.⁹⁹

Despite its critical importance, there is no jurisdiction that provides a legal definition for smart contracts.¹⁰⁰ Smart contracts are technically defined as event-driven programs running on a distributed, decentralized, shared, and replicated ledger. These contracts can transfer assets without any legal permission,¹⁰¹ which makes it difficult to apprehend them from a civil law perspective and assimilate them into civil law contracts.¹⁰² There is a substantial regulatory gap in the execution, such that smart contracts do not substitute lawyers.¹⁰³ Instead, it is advised to adapt smart contracts to accommodate legal requirements, as security tokens are not a completely new asset class but the evolution of traditional ABS.¹⁰⁴ The similarities between securitization and tokenization enable the revision of existing securitization policies to include tokenization.

Experts have identified several obstacles to providing legal status to smart contracts¹⁰⁵—first, the need to maintain technological neutrality in regulations, and second, the multiple standards and functionalities available for specific codes and blockchains. For instance, the standards governing fungible tokens will differ from those governing the codes of non-fungible tokens. Therefore, in addition to defining these standards, regulators also need to define a separate set of guidelines to determine whether a particular

⁹⁷ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

⁹⁸ <https://corpgov.law.harvard.edu/2018/05/26/an-introduction-to-smart-contracts-and-their-potential-and-inherent-limitations/>

⁹⁹ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

¹⁰⁰ During the time of writing the report, December 2021.

¹⁰¹ https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3095933

¹⁰² <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

¹⁰³ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

¹⁰⁴ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁰⁵ <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

smart contract is subject to those standards.¹⁰⁶ For instance, in Luxembourg, regulators will have to clarify that a standard smart contract for security tokens will either have to comply with Prospectus Law or Prospectus Regulations depending upon the terms of the offer.¹⁰⁷

As a result, the legal status of smart contracts is yet to be defined in many jurisdictions, resulting in a lack of enforceability, and giving rise to consumer protection concerns. Several countries around the world have set regulations and policies to legitimize the security token asset class including the U.S. Securities and Exchange Commission (SEC) and authorities in Hong Kong and Singapore.¹⁰⁸ Security tokens also differ significantly from tokens issued as part of an “Initial Coin Offering” (ICO). Coins generated through ICOs are usually intended to be used in the ecosystem or on the platform of the issuer as opposed to representing ownership rights of the issuer.¹⁰⁹ On the other hand, tokens from a security token offering (STO) could represent an equity stake in the issuer, similar to an initial coin offering in traditional financial markets.

Currently, since there are no global standards governing blockchain transactions they require verification by a Trust Service Provider.¹¹⁰ Some of these standards could be integrated into smart contracts, but that impacts the system’s cost-effectiveness. National differences in contract law, in the form of language and authorization, make it more difficult to assume the legitimacy of smart contracts. In 2019, the United Kingdom became one of the few jurisdictions¹¹¹ to provide smart contracts with a legal status, such that all common rules pertaining to traditional contracts are also applicable to smart contracts.¹¹²¹¹³

e. Cyber security concerns

The use of smart contracts also raises major cybersecurity concerns. Their characteristic features like automation and immutability increase their vulnerability to cyber hacks and expose investors to fraudulent practices. As discussed earlier, the lack of a globally acceptable standard prevents legal clarity on key provisions relating to claiming ownership rights, integration of AML/KYC requirements, admin rights, and integration with secondary markets are not considered. As a result of these and other loopholes, according to MIT, hackers have successfully stolen over \$2 billion worth of cryptocurrency since

¹⁰⁶ <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

¹⁰⁷ <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

¹⁰⁸ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁰⁹ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹¹⁰ <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

¹¹¹ The Canadian government and some U.S. states of the USA have also legally accepted the use of smart contracts in administrative procedures. https://assets.ey.com/content/dam/ey-sites/ey-com/en_ca/topics/blockchain/ey-how-blockchain-can-enable-smarter-contracts-in-infrastructure.pdf?download

¹¹² https://35z8e83m1ih83drye280o9d1-wpengine.netdna-ssl.com/wp-content/uploads/2019/11/6.6056_JO_Cryptocurrencies_Statement_FINAL_WEB_111119-1.pdf

¹¹³ <https://www.simmons-simmons.com/en/publications/ck400ievr65o00b44el9cfb4p/what-is-the-legal-status-of-cryptoassets-and-smart-contracts->

2017.¹¹⁴ Some of these funds were taken by hackers exploiting the “51% rule” vulnerability inherent in proof of work blockchains, where an entity controlling over 51% of the computing power within a blockchain network can create “fraudulent but validated records.” A smart contract can be replicated by exploiting every detail of its design, implementation, and execution making transactions vulnerable.

51% Attack:¹¹⁵

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.

Most countries have their own securities and AML/KYC regulations, requiring issuers to comply with varying regulatory regimes.¹¹⁶ For instance, a token regulated in a European country might not be regulatory compliant or considered as a security in the United States.¹¹⁷

To ensure cyber security, it is important for tokens to comply with AML/KYC laws. It is critical to maintain accountability of ownership of tokens, which would require collaboration with security token exchanges to track ownership. This compliance requires expert supervision and subsequently increases the costs to an issuer.

In addition to the above considerations, for a smart contract to be appropriately implemented, it is necessary to integrate databases and processes across the supply chain. Regular software updates and strengthening the software development team to keep up with the regulatory changes is essential. It is also important to set up and understand new business protocols to suit the requirements of the stakeholders. Furthermore, since tokenization of infrastructure is a big commitment, it is imperative to select a project with a proof of concept that is structured and well defined where business partners can provide identity, and where terms and success of transaction can be easily measured.

¹¹⁴ <https://www.technologyreview.com/2019/02/19/239592/once-hailed-as-unhackable-blockchains-are-now-getting-hacked/>

¹¹⁵ <https://www.iisd.org/publications/tokenization-infrastructure-blockchain-based-solution-financing-sustainable>

¹¹⁶ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

¹¹⁷ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

5. Examples of conducive regulatory frameworks for implementing tokenization of infrastructure

The use of blockchain technology has the potential to disrupt how infrastructure is currently being financed if there is an enabling regulatory environment. Countries with a strong legal framework for DLT-based securities present an attractive destination for issuing these security tokens and participating in the token economy. The following are a few leading examples:

a. United States¹¹⁸

As an emerging technological solution, tokenization of infrastructure is subject to different laws at the federal and state levels. In 2019, 28 states introduced legislation for blockchain, with 27 bills and resolutions enacted and adopted. However, legislation in some states only affect those particular states and have no applicability at the federal level.

Due to regulatory limitations, generally the equity of the special purpose vehicle that owns the infrastructure project is tokenized instead of the ownership rights of the underlying asset. The definition of “security” is broad and includes stocks, bonds, and other standard investment instruments including an “investment contract.” Since the SEC considers most tokens as securities, they will be subjected to relevant federal and state laws.

The SEC introduced a framework in 2019 to assist market participants in determining whether a particular digital asset is an investment contract and therefore a security under U.S. federal security laws. The term “digital asset,” used in the framework and subsequent statements, refers to an asset that is issued and/or transferred using DLT including, but not limited to, coins and tokens.

According to the SEC, to test if a token can be considered as an investment contract and qualifies as a security, it will have to undergo a “Howey Test”. To qualify, the following criteria must be met:

- a. It is an investment of money
- b. In a common enterprise
- c. Where there is a reasonable expectation of profits
- d. Any profits will be derived from the entrepreneurial or managerial efforts of others

While the criteria seem reasonable, not all DLT tokens qualify as securities. For instance, in 2018, the SEC declared that Bitcoin and Ethereum are not securities. If the network on which the token/coin is used is

¹¹⁸ <https://www.yklaw.us/are-tokens-securities/>

sufficiently decentralized the purchasers could no longer expect reasonable entrepreneurial efforts.¹¹⁹ In 2020, the SEC proposed Rule 195 ensuring that a safe harbor of three years would be provided from the first token sale to become “sufficiently decentralized,” and therefore not likely to be a security.

If a token qualifies, it needs to register with the SEC or satisfy certain conditions for an exemption (Regulation A+, Regulation CF, Regulation D or Regulation S). Failure to do so will result in substantial civil penalties and give investors the right to revoke their investment with full compensation.¹²⁰ Each of these regulations impose different requirements on the offering including rules on eligible investors, resale restrictions, and investment limits.

In 2020, the SEC issued a statement regarding the custody of digital securities by special purpose broker dealers. The statement sets forth the SEC’s position that for a period of five years, a broker-dealer operating under certain circumstances will not be subject to SEC enforcement action. This is on the basis that the broker-dealer has legally obtained and maintained physical possession or control of the digital asset securities under the securities exchange act of 1934. This also establishes and implements policies and procedures designed to mitigate the risks associated with conducting a business in digital securities and provides customers with certain disclosures regarding the risks in engaging in digital security transactions.

In July 2020, the Commodity Futures Trading Commission (CFTC) announced plans to develop a holistic framework to promote responsible innovation in digital assets as a part of its strategic plan for 2020–2024. In September 2020, the Office of the Comptroller of the Currency (OCC) allowed national banks to provide permissible banking services to any lawful business they choose, including cryptocurrency businesses as long as they effectively manage the risks and comply with applicable law including those relating to the AML and Bank Secrecy Act (BSA) provisions. This includes reserves backing stable coins provided that stable coins are kept in a hosted wallet (controlled by a trusted third-party contrary to un-hosted wallets controlled by the user who is also the owner of the assets stored).

b. Luxembourg

Luxembourg is currently one of the most conducive jurisdictions for infrastructure tokenization. Its legal framework is designed to enable the benefits of blockchain that are the most relevant and beneficial for the country, such as using blockchain to eliminate intermediaries in the asset management industry.¹²¹

A new draft bill (“2021 law”) allows central account keepers and settlement organizations in Luxembourg to have legal certainty concerning the use of DLTs for issuing and circulating dematerialized securities. It

¹¹⁹ <https://hbr.org/2017/01/the-truth-about-blockchain>

¹²⁰ <https://dilendorf.com/resources/tokenization-of-real-estate-what-why-and-how.html>

¹²¹ <https://www.toprankedlegal.com/tokenised-securities-in-luxembourg-concept-and-legal-considerations-to-be-taken-into-account-upon-an-issuance/>

will, however, not be possible for entities to issue tokens on their own since it is mandatory to use the services of a central account keeper or settlement organization. Another similar law (“2013 law”) recognized token transfers via DLTs as equivalent to transfers between securities accounts. This permits the dematerialization of securities other than bonds, as even shares could be issued as native tokenized securities without requiring a corresponding certificate.¹²² Issuance of tokenized bonds as bearer securities does not require the issuance of a corresponding certificate for each bond, given that possession accords ownership.

c. Liechtenstein

Liechtenstein chose a different approach by developing a holistic regulatory framework dedicated to the token economy. In January 2020, Liechtenstein became the first country with comprehensive regulatory guidelines under the Blockchain Act or Token and Trusted Technology Service Provider Act, the *Gesetz über Token und VT-Dienstleister* 54/2019 of Liechtenstein. The guidelines address the legal nature and regulates the “*Physischen Validator*,” an entity that verifies the condition of the “tokenized” asset.¹²³

Asset-backed tokens in Liechtenstein could be regulated as digital assets if they meet the following criteria: the Asset-backed tokens must represent claims of either proprietary or obligatory nature against third parties. The legal effect may be achieved by the parties on the basis of the principle of freedom of contract, regulated in several EU countries, but should be established by law following the examples of *Gesetz über Token und VT-Dienstleister* of Liechtenstein.

Digitalizing assets will not change their legal status; asset-backed tokens should comply with the rules and requirements governing non-digital assets. Parties must comply with the local rules and requirements of the place where the asset is located to take specific decisions on their property. These include transferring ownership or creating limited property rights, which may require legal acts to be concluded in writing or observation of other formats.

d. Switzerland¹²⁴

In 2020, Switzerland passed the Distributed Ledger Technology (DLT) Act enabling innovation using ledger-based technologies. Unlike in Liechtenstein, this DLT Act is not a self-contained law but is a blanket act modifying existent civil law (in respect of securities), financial market infrastructure law (DLT trading facility), the Banking Act, and bankruptcy regulations.

A key feature of the act is the formal recognition of uncertificated registered securities or digital securities that can be transferred without financial intermediaries. This provides legal certainty on the ownership

¹²² <https://www.oecd.org/daf/fin/financial-markets/Regulatory-Approaches-to-the-Tokenisation-of-Assets.pdf>

¹²³ <http://housing.urv.cat/wp-content/uploads/2021/05/WP-1-2021-Digital-tokenization-property-rights.pdf>

¹²⁴ <https://www.imd.org/news/updates/new-tech-act-Switzerland-secures-legal-environment-blockchain-flourish/>

and transfer of those tokens. Owners of these tokens now have the right to receive interest payments and make a debt claim against a third party. Prior to this law, automated DLT applications were termed invalid since for any claim (including assignment contracts) to be considered valid, legally binding, and transferrable, a hand or digital signature was required. The new law enables the issuance and transferability of uncertificated register securities within the token's register and DLT system without a signature. This legal provision validating the transfer of ownership of securities makes Switzerland a frontrunner in the field.

The DLT Act of Switzerland permits companies to issue both traditional and uncertificated registered securities by accepting a record of shareholdings on a blockchain as a valid shareholder register. However, a company must maintain a consolidated overview of the securities maintained on different shareholder registers. After receiving consent from respective shareholders, individual companies need to amend their existing articles of association to include uncertified registered securities.

e. France

France was one of the first countries to provide legal standing to blockchain and to use the technology for registration and securities transfers. The “Blockchain Order,” a regulatory framework established in French law to govern the representation and transmission of unlisted financial securities via DLTs, was introduced in 2017. The law extended a 2016 Act allowing the use of DLTs for recording the issuance and sale of SME minibonds giving the possibility to other securities (unlisted and debt) to be issued, registered, and transferred using DLTs instead of traditional securities accounts.

In 2019, the *Plan d'Action pour la Croissance et la Transformation des Entreprises*, also known as the *Loi Pacte* (PACTE Law), was enacted in France to foster entrepreneurship and innovation, facilitating the growth of businesses and creating jobs.¹²⁵ The framework is claimed to be one of the most exhaustive frameworks on digital assets covering regulatory, fiscal, and accounting aspects. The law is said to govern blockchain applications and provide guidance to crypto asset service providers (CASPs) on the issuance and management of DLT related services.¹²⁶

According to the PACTE Law, investments in digital assets can be made either directly by an investor to an issuer by subscribing units/shares or by concluding financial contracts involving one or more digital assets as underlying assets. A digital asset can consist of a token represented as a crypto asset (like cryptocurrency) or any digital representation of a value that is neither issued nor guaranteed by a central bank or by a public authority. The latter category is not necessarily related to a currency but is accepted by entities or natural persons as a means of exchange that can be transferred, stored, or exchanged

¹²⁵ <https://www.debevoise.com/-/media/files/insights/publications/2019/07/20190708-loi-pacte-french-regulator-implements.pdf>

¹²⁶ <https://www.gouvernement.fr/en/france-adopts-a-regulatory-framework-for-blockchains>

digitally.¹²⁷ Infrastructure tokenization falls within this definition, therefore recognizing infrastructure tokens as digital assets.

This framework could potentially become a leading jurisdiction establishing future standards for crypto assets on a European scale. The objective of the framework is to promote the development of a dynamic and robust ecosystem that combines the capacity for innovation and transparency while providing high security to savers and investors.¹²⁸ The law also permits the issuance of an ICO visa on the primary market, making it possible for issuers to request a visa from the French Financial Market Authority prior to their ICO. However, certain legal obligations relating to issues of cybersecurity, equity capital, and insurance need to be complied with. For example, a custodial service is an obligation to restore control of digital assets held in custody. For certain service providers, the optional approval is complemented by registration in respect of regulations against money laundering and financing of terrorism.¹²⁹

f. European Union (EU)

As a part of the EU Digital Finance Package in 2020, the European Commission published the draft Regulation for Markets in Crypto Assets (MiCA) to foster innovation and competition in digital finance while controlling associated risks. Largely inspired by the French PACTE Law of 2019, the regulation intends to regulate players in crypto markets rather than the assets themselves. The regulation will apply to any person issuing crypto assets, or associated services. However, it will not apply to security tokens that are already subject to existing EU regulatory regimes.¹³⁰

The draft regulation intends to add legal certainty and support innovation, while protecting consumers. Experts anticipate the MiCA regulation to increase the burdens for issuance of crypto assets and provision of associated services and have termed it as a “patchwork quilt of existing EU regulations” amended to form a degree of proportionality.

¹²⁷ <https://www.iflr.com/article/b1lmx4qdt77xtq/frances-new-pacte-law-progress-at-the-cost-of-protection>

¹²⁸ <https://www.gouvernement.fr/en/france-adopts-a-regulatory-framework-for-blockchains>

¹²⁹ <https://www.gouvernement.fr/en/france-adopts-a-regulatory-framework-for-blockchains>

¹³⁰ <https://www.sygnia.io/blog/what-is-mica-markets-in-crypto-assets-eu-regulation-guide/>

6. Applicability in Emerging Markets and Developing Economies (EMDEs)

As observed, all the current conducive regulatory frameworks belong to technologically and financially advanced countries like Switzerland, the United States, and Luxembourg. Emerging markets and developing economies (EMDEs) currently lag behind in both the resources required for developing pilots as well as regulatory frameworks for governing projects. However, the tokenization of infrastructure has the potential to positively impact EMDEs the most. Infrastructure finance in EMDEs is faced with government deficits, transparency issues, insufficient financial efficiency, as well as lack of performance tracking, which tokenization can address.

Tokenization in developing countries can elevate private sector confidence via improving infrastructure asset liquidity, while opening access to small-scale projects and enlarging participation in infrastructure development. EMDE governments can benefit from prospective administrative and financial efficiencies brought about by automated auditing, enhanced project monitoring, and lower financing costs. Small-scale projects often deliver the most economic and social impact per dollar spent. However, these projects face barriers to financing due to high transaction costs due to their small size. By tokenizing small-scale infrastructure projects, due-diligence and transaction costs can be decreased significantly. Taken together, tokenization has the impact to transform both the economies and people's lives in EMDEs.¹³¹ However, to unlock to complete benefits of blockchain through tokenization, it is important to carefully examine and overcome the potential risks and barriers.

Considerations and Recommendations:

a. Regulatory harmonization:

For mainstream adoption through a global user base, STO regulation of different jurisdictions needs to be harmonized. In the EMDE context, policymakers need to update the legal and regulatory frameworks to address the opportunities and risks associated with tokenization. Establishing the legal status of asset-backed tokens and smart contracts must be prioritized. Taxation policies should be modernized, such that asset tokens are aligned for tax purposes. A careful balance of regulation should be maintained to ensure the market is both secure and favorable for the private sector to participate in.

Since it is less feasible to establish a global standardized legal and regulatory framework across jurisdictions in the short term, an alternate working group of stakeholders could be initiated.¹³² Experts have proposed that multilateral development banks (MDBs) like the World Bank and Asian Development Bank (ADB) along with nongovernmental organizations initiate a working group to develop a process to test "low-hanging-fruit" applications towards more broadly defined infrastructure investment domains.¹³³ A hybrid globalized governance and reporting system to

¹³¹ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹³² https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹³³ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

integrate the specific tokenization requirements of target countries can be established to create global alignment of smart contracts.¹³⁴

b. Pilot testing and sandboxes

Due to the high risk involved in EMDE infrastructure investment, governments and international organizations can actively support and create awareness about the advantages of innovative technology. It is vital to educate the “potential investors” about the opportunities and risks associated with tokenization as it will be the first time that retail investors worldwide will be granted direct access to the EMDE infrastructure assets.¹³⁵ This will avoid risky investments and unexpected losses.

There is a need for developing pilots and regulatory sandboxes for promising-use cases to gain practical insights and test the advantages and constraints in a real-world setting.¹³⁶ To test and learn about the technology, some jurisdictions like South Africa and the Philippines¹³⁷ have already established regulatory sandboxes to allow for a more flexible approach in consultation with the regulator. Sandboxes create a safe space in which businesses can test innovative products, services, business models, and delivery mechanisms in a live environment without immediately incurring all the normal regulatory consequences.¹³⁸

c. Capacity building

Tokenization is a novel concept using a nascent technology. It requires capacity building of decision and policymakers to facilitate the development of regulatory frameworks¹³⁹. Successful-use cases can further promote these innovative financing mechanisms and the use of blockchain technology in this context.¹⁴⁰ Platforms like the OECD blockchain policy center and the World Bank’s blockchain lab should be encouraged to create knowledge exchange forums,¹⁴¹ especially with EMDE countries. National governments and international organizations like the World Bank can work with researchers and industry practitioners to establish case studies for specific countries to assess the local opportunities and risks associated with tokenization.

¹³⁴ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹³⁵ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

¹³⁶ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹³⁷ <https://www.bakermckenzie.com/->

/media/files/insight/publications/2020/05/a_guide_to_regulatory_fintech_sandboxes_internationally_8734.pdf?la=en

¹³⁸ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹³⁹ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹⁴⁰ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹⁴¹ https://abfer.org/media/abfer-events-2020/specialty-conf/12_paper_Tian_Asset-Tokenization-A-Blockchain-Solution.pdf

7. Case Studies: Infrastructure tokenization pilots to date

Year	Name of project	Value raised	Issuer	Country	Description
2018	Belt and Road Initiative	2 billion RMB		China	A hydroelectric power plant with a return of over 4% and an upfront cost of 2 billion RMB was tokenized using blockchain. The project integrated core members of the community
2020	Democratizing infrastructure projects ¹⁴²	Entry price is €10,000 to attract qualified investors	Digibrixx	Luxembourg	Digibrixx breaks down property into tokens, making it accessible to everyone. To ensure transparency is maintained, every project is covered by a detailed presentation with the percentage of funding already raised presented, and an estimate of the annual performance stated. The company is considering a rollout of an online trading platform that allows investors to sell, buy, or even exchange their tokens easily.
2021	Investing in sustainable forests ¹⁴³	Providing 3% p.a for 10 years and 4-6% IRR on projects, with token price being €1.	Ekofolio	Luxembourg	A start-up operating a digital platform allowing users to purchase tokens representing stakes in forests bought and managed by the company's SPV. These tokens generate relatively stable dividends and potentially increase in value if the timber price or land value rises.

¹⁴² <https://www.digibrixx.eu/>

¹⁴³ <https://www.ekofolio.com/>

	Liquid Token ¹⁴⁴	Annual return of 7%-12% is promised.		Australia	An investment platform offering investments into tokenized sustainable development and impact projects. The platform offers an innovative financing approach to protect oceans, restore nature, and empower communities. In 2019, a joint venture was proposed with the largest U.S. non-bank securities broker. ¹⁴⁵
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Other relevant examples for real estate

2018	Property in Manhattan ¹⁴⁶ (Failed project)	\$30 million	Propellr and Fluidity	United States	In December 2018, blockchain startup Fluidity was to create digital access to property rights in a 12-unit Manhattan condominium complex in conjunction with broker-dealer Propellr. Investors would have had the option to receive either analog or digital interests in the securities. However, the deal quietly collapsed, as a result of the “prematurity of institutional interest.” ¹⁴⁷
2018	St. Regis Aspen Resort in Colorado ^{148,149}	\$18 million Minimum investment \$10,000	Aspen Digital	United States	The St. Regis Aspen is a resort with 179 rooms and multiple food and beverage outlets. The successful offering was made available through Templum markets, an SEC-registered operator for the

¹⁴⁴ <https://liquidsecurities.net/>

¹⁴⁵ <https://www.adb.org/sites/default/files/publication/566271/adbi-wp1079.pdf>

¹⁴⁶ <https://www.hbs.edu/faculty/Pages/item.aspx?num=55466>

¹⁴⁷ <https://tokenist.com/propellr-and-fluiditys-nyc-real-estate-tokenization-deal-falls-through/>

¹⁴⁸ <https://venturebeat.com/2018/10/09/elevated-returns-gets-18-million-for-st-regis-aspen-resort-tokenized-real-estate/>

¹⁴⁹

<https://deliverypdf.ssrn.com/delivery.php?ID=241124005024106087114023000117014066007003009040033092067067109077117029028087027102114017055054029044016126103018087126119018008000007082048024120091084016068081074061093077021126097093019092070110017111072115102096019100117004074001080104028000082021&EXT=pdf&INDEX=TRUE>

					<p>initial offering and secondary trading of digital assets as securities through its Alternative Trading System (ATS). Marketing was supported by a crowdfunding platform called Indiegogo. The tokenized securities were exempt of registration via Regulation D and therefore were offered and sold only to accredited investors by means of a private placement.</p> <p>Dividends are planned to be distributed on chain to token holders using Ether (ETH). Secondary trading is provided by Templum to whitelisted investors.</p> <p>A portion of the resort was tokenized to form a single real estate investment trust (REIT). According to the deposit agreement, each Aspen Digital Token will represent an indirect ownership interest in one deposited share of the common stock of the REIT. It is essentially an REIT structure placed on blockchain programmed with smart contracts. The REIT makes the structure tax efficient while blockchain simplifies transactions.</p>
<p>2019</p>	<p>Belval – First real estate transaction in Luxembourg¹⁵⁰</p>	<p>Token holders can determine their size of investment</p>	<p>Creahaus S.A and Espace Invest S.A</p>	<p>Luxembourg</p>	<p>The tokens are securely stored in a “zeroelectronic” physical vault provided by Coinplus, a start-up located in</p>

¹⁵⁰ <https://tokeny.com/first-completed-real-estate-transaction-via-blockchain-in-luxembourg/>

		with the minimum set at €1000			Luxembourg Technoport. The income generated through the tokens are proportionally distributed to the token holders.
2019	Flims Laax Falera Resort ¹⁵¹		Weisse Arena Gruppe – Daura register	Switzerland	<p>Digital micro-shares are issued on the Daura registered from telecom giants Swisscom. The crypto shares are encoded in smart contracts for transactions.</p> <p>The ski resort also plans to issue its own cryptocurrency GURU (Greatest User Return Unit) for using the resort’s facilities.</p> <p>The success of local businesses and housing prices are linked to the success of the resort.</p>
2019	Development of Domaine d’Hestia in Siant Andre Lez Lille – Tokenized real estate bonds for development operation ¹⁵²	<p>€3.1 million</p> <p>Fixed yield of 7.5% per year on bonds</p>	Capelli	Switzerland	<p>Capelli is a real estate developer that tokenized bonds on its real estate development operations. The operation was done through a Luxembourg vehicle, and the vehicle was tokenized.</p> <p>The transaction was financed in less than a week by a dozen investors.</p>
2019	AnnA Real Estate Tokenization – first real estate backed STO ¹⁵³	€6.5 million	Equisafe Investment Platform	France	AnnA Villa is a luxury property located in suburban Paris. The property rights are fully encoded in the blockchain, encrypted on EquiSafe virtual registry. Each token contains terms and conditions for the

¹⁵¹ https://www.swissinfo.ch/eng/new-innovation_the-blockchain-revolution-emerges-on-main-street/44870190

¹⁵² <https://wecangroup.ch/the-capelli-real-estate-group-closes-its-first-tokenisation-operation-with-wecan-tokenize/>

¹⁵³ <https://tokenist.com/equisafe-provides-update-on-frances-first-real-estate-backed-sto-has-15-tokenizations-planned/>

					purchase, sale, and exchange of securities as well as rights to dividends, voting, etc.
2019	SharesPost California - Transfer of ownership of private shares ¹⁵⁴ with BlockchainCapital (BCAP) token being the first tokenized security listed on the SharePost Marketplace. ¹⁵⁵	\$4.5 billion total transactions done by SharePost.	SharesPost	United States	SharePost introduces a new system to provide automated liquidity to private firms by generating security tokens written on a claim to these privately held shares. Tokens derive their value from a pool of shares most often pledged by founders, VCs, and large shareholders seeking liquidity. The shares cannot be traded independently but the tokens linked to their value are traded in a global settlement system called GLASS (Global Liquidity and Settlement System). This system functions in full compliance with SEC regulations and is considered as an alternative trading system.
2020	Bahnhofstrasse, Zurich ¹⁵⁶ – first global real estate portfolio worth more than 1 billion CHF. ¹⁵⁷	Financed with a token offering of €120 million	BrickMark	Switzerland	Bahnhofstrasse 52 is prime real estate of Zurich. BrickMark issued digital tokens underpinned by a bond that can be bought and traded by investors. The company funded 20% of the purchase by giving the seller RFR Holding a batch of tokens, or a stake in the future income of the building. The tokenization exhibits several core qualities of STOs. Efficiencies offered by

¹⁵⁴ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁵⁵ <https://www.businesswire.com/news/home/20190110005168/en/SharesPost-Marketplace-to-Provide-Compliant-Secondary-Liquidity-for-Security-Tokens>

¹⁵⁶ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁵⁷ https://www.swissinfo.ch/eng/tokenised-investment_slice-of-prime-zurich-real-estate-sold-on-blockchain/45495450

					blockchain technologies are often on single assets as compared to portfolios. Since single assets are free from complex, non-linear payout relationships that make traditional ABS risky. ¹⁵⁸
2021	<p>First platform to offer digital shares of tokenized real estate on the public Stellar Network blockchain in the EU.¹⁵⁹</p> <p>Also launching the market's first alternative investment vehicle in Ukraine led by the government.</p>	<p>To become a qualifying token holder, a min. of €1000 SLTs should be held (SLT is a native token of Smartlands Network).</p> <p>Oracles are obliged to reserve 1/3 of all fee income to be distributed to qualifying token holders, paid out in SLT tokens.</p> <p>Listing fee of €5000, 5% of all capital raised, ongoing listing fee of €1500 to be paid annually, no commission will be charged for buyers in the secondary market, but sellers of the</p>	Smartlands Network	UK, EU, multiple jurisdictions	<p>Smartlands seeks to be a worldwide agnostic ecosystem of Asset-Backed Tokens, bringing together profitable real economy assets, institutional, and retail investors in multiple jurisdictions. The transactions are done on a public blockchain to provide oversight warranted and required by the asset type.</p> <p>The company has issued Compliance Oracles to perform required checks and verification of assets. It will be the responsibility of the issuer to disclose if an asset requires a compliance check or not. Compliance oracles provide flexibility and could be approved by financial authorities.</p>

¹⁵⁸ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁵⁹ <https://slt.finance/>

		asset tokens on the platform will be charged 1% of each sale.			
	Desygnate – Primary market issuance platform ¹⁶⁰ SygnEx – Secondary market trading venue ¹⁶¹		Sygnum – Digital Assets bank	Switzerland, Singapore	Digital assets bank Sygnum seeks to introduce sources of funding for small companies by creating and trading shares on blockchain. Illiquid assets like venture capital, real estate, and arts and collectibles markets are targeted. The aim is to translate traditional assets into blockchain-compatible digital tokens to increase liquidity.

Source: Created by report authors

Take-aways from the case studies

The cases above are examples of issuers who have either already tokenized or are currently in the process of tokenizing infrastructure. The cases present both successful and unsuccessful examples of infrastructure tokenization from around the world. However, the cases are only analyzed from the information provided from an issuer perspective; the investors’ experience and satisfaction with the transaction is not known.

1. While the list of examples presents several “successful” cases, there are also a few that have failed, the reasons for which are unclear and largely unreported. There is no clear pattern identified amongst the failed projects. However, the lack of technical understanding of blockchain and unrealistic expectation of profits by both issuers and investors could have been a reason. Most investors choose to follow the “trend” of investing in digital assets but have insufficient knowledge about the “actual” benefits and risks of blockchain technology, including regulatory challenges. There is also significant confusion between “cryptocurrencies” and the “tokenization of securities”.
2. Infrastructure can be tokenized in different ways and at different stages of the project like for financing through REITs; tokenizing an SPV for operation of the infrastructure; or offering digital micro-shares of established buildings and streets. Additionally, while some property tokens

¹⁶⁰ <https://www.sygnum.com/solutions/tokenization/>

¹⁶¹ <https://www.sygnum.com/solutions/tokenization/>

represent ownership rights with the ability to vote and participate in decision making, others are programmed solely to claim dividends and profits.

3. The lack of a globally accepted governing system complicates the governance of potential tokenization projects. The regulation of crypto assets vary significantly across countries. There are only a few jurisdictions in the world that have designed specific regulatory frameworks to govern digital assets as discussed in the previous section. While some of these frameworks are comprehensive and clear, like that of Switzerland and Luxembourg, many others, like Gibraltar, United Arab Emirates, Turkey, and Germany¹⁶² are still in the development phase and lack clarity.
4. Furthermore, there is a varying degree of legitimacy given to digital tokens across countries. For instance, while the United States, Luxembourg, and Liechtenstein accept tokens as digital assets, other countries like Algeria, Bolivia, and Vietnam have substantive restrictions in place. Many other countries like Anguilla, Canada, Mexico, India, and Uzbekistan¹⁶³ have legalized security tokens but they have not been defined by regulators. There are also multiple countries like China and Qatar¹⁶⁴ where digital tokens have been termed illegal or are currently unknown in several other countries.¹⁶⁵
5. Each of the examples targets investors of different levels of wealth. Some of the examples seek to democratize infrastructure by offering micro-digital shares, while others seek to attract accredited investors of high net worth to invest in exotic luxury properties. Most of the cases have defined a “minimum investment”. For instance, the minimum investment in the Belval property of Luxembourg is €1000, St. Regis Aspen Colorado is \$10,000, and in the sustainable forests offered by Ekofolio it is €1. This amount depends upon the business model of the issuer and their risk-taking appetite.
6. In most cases, issuers are obligated to register with the relevant local authorities, like the national Securities Commission. As discussed in the previous sections, this registration process is often both costly and tedious. However, in some jurisdictions, certain issuers are exempt from registering if they fall under specific categories. For instance, in the St. Regis Aspen example, the tokenized securities were exempt from registration via Regulation D and therefore were offered and sold only to accredited investors by means of a private placement memorandum.
7. Most of the jurisdictions that have legal provisions for digital assets require issuers to comply with specific AML, KYC, and counter-terrorist financing (CFT) laws and sanctions screening obligations to ensure transactions are done with verified investors. Blockchain is being applied for work

¹⁶² <https://blog.stomarket.com/defining-security-tokens-list-of-all-countries-with-legal-definitions-of-digital-securities-6b19eab6c330>

¹⁶³ <https://blog.stomarket.com/defining-security-tokens-list-of-all-countries-with-legal-definitions-of-digital-securities-6b19eab6c330>

¹⁶⁴ <https://hackernoon.com/asset-backed-tokenization-everything-you-wanted-to-know-9m4m32n0>

¹⁶⁵ <https://www.hadefpartners.com/News/536/The-Future-of-Crypto-Assets-Regulation-in-the-UAE#:~:text=Currently%2C%20Algeria%2C%20Bolivia%20and%20Vietnam,digital%20tokens%20such%20as%20Bitcoin.>

dealing with the tokenization of property rights from a domestic law perspective, and in some cases with the aim to replace, complement, or modify existing Land Registries with the technology. For example, since 2017, the Swedish land registry has been using blockchain to a certain extent.¹⁶⁶

8. One clear observation is that western countries, including the United States and those in Europe (especially Luxembourg and Switzerland), are frontrunners in the field—both in terms of sophisticated regulatory frameworks and number of successfully issued tokens. The EU is developing the space actively by funding several blockchain start-ups like Ekofolio. Another observation is there are currently very few “government-led” tokenization projects outside of the EU. Of the literature found through desk research and interviews with stakeholders, only one example was identified: the Ukrainian government establishing a market-first alternate investment vehicle in collaboration with SmartLands Network.¹⁶⁷ It is obvious that government involvement is likely to ease the implementation of the project, however, the status of this particular project is unknown. The frontrunners of Asia include Singapore and Hong Kong by actively developing the field and actively adopting DLT technologies. These examples indicate a need for a robust and stable government to develop strategies for the adoption and governance of digital assets.
9. For security tokens to become mainstream methods of asset tokenization, interest and active participation by various stakeholders like businesses, investors, regulatory bodies, and governments are required. At times, investors must be incentivized to participate to ensure the successful implementation of the project, like in the case of the Belt and Road Initiative. In this case, individuals were incentivized to invest by offering a 50% discount on future energy expenditure occurring from the hydroelectric power plant being financed. According to experts,¹⁶⁸ without the use of blockchain, this green energy project would not have been financed. The use of blockchain technology facilitates self-financing that could potentially be more sustainable if a conducive regulatory framework is established. This could especially be useful for financing sustainable infrastructure solutions like exhibited by the start-up Ekofolio that tokenizes parts of forests.
10. As discussed earlier, Switzerland is one of the frontrunners of tokenizing infrastructure. Prime real estate on Bahnhofstrasse in Zurich has been tokenized to become the first global real estate portfolio valued at over 1 billion CHF. This case exhibits several core qualities of STOs—first, the advantages of blockchain technology is more effective on single assets compared to portfolios. One reason for this could be the relative ease offered in comparison to complex, non-linear

¹⁶⁶ <https://qz.com/947064/sweden-is-turning-a-blockchain-powered-land-registry-into-a-reality/>

¹⁶⁷ <https://smartlands.io/news/smartlands-announces-partnership-agreement-with-ukraines-oldest-established-commodity-exchange/>

¹⁶⁸ https://www2.deloitte.com/content/dam/insights/us/articles/4406_Belt-and-road-initiative/4406_Embracing-the-BRI-ecosystem.pdf

payout relationships that make traditional ABS riskier.¹⁶⁹ Consequently, there are several examples of single real asset tokenization from around the world including the St. Regis Aspen in the United States, AnnA Villa in France, and Belval in Luxembourg. Experts predict this trend to increase in the future, attracting more investors to become a market worth over \$1.4 trillion.¹⁷⁰

¹⁶⁹ <https://wip.mitpress.mit.edu/pub/pq3p2jw2/release/1>

¹⁷⁰ <https://cointelegraph.com/news/tokenized-real-estate-market-could-hit-1-4t-despite-a-slow-start-report-claims>

8. Future of Tokenization – The future and alternatives to blockchain

As discussed throughout the paper, tokenization has several advantages that could ease business processes and potentially improve profitability. Supporters of blockchain claim that the adoption of disintermediating technologies like blockchain is no longer a question of “if,” but rather of “when”.¹⁷¹ The full potential of the technology is yet to be explored and proved to be disruptive for several industries.

However, there are several regulatory challenges delaying the implementation of tokenization projects. While some jurisdictions have been frontrunners in providing regulatory clarity, many others are still lagging behind when it comes to the tokenization of securities. The designated roles and responsibilities of trust-related functions like digital wallets and notaries should be re-thought. These instruments require technical and regulatory streamlining to ensure efficient and mainstream adoption of blockchain technology. There is also a need to reevaluate the roles of traditional regulators, with the increase in innovative digital assets. These assets are unlike traditional securities and need faster and more flexible management, while protecting the interests of both issuers and investors. A homogeneous regulatory framework should be facilitated by combining the know-how and innovation of traditional and new players respectively.

There are also several alternatives to blockchain¹⁷² having similar or enhanced advantages. The following are a few examples:

a. Centralized databases

One of the key advantages of blockchain technology is its decentralized nature. However, this characteristic adds to computational needs and energy consumption problems. Newer blockchain implementations show improvement, however they are still slower in comparison to well-managed centralized databases.¹⁷³ For instance, Solana blockchain enables 50,000 to 65,000 transactions per second, terming it the “fastest blockchain on the planet” in August 2022.¹⁷⁴ It has successfully processed 15 times the number of transactions compared to Ethereum at a fraction per second.¹⁷⁵ VisaNet also proves that complex functions like securing transactions, improving product tracking, facilitating product recalls, and protecting privacy while maintaining audit trails can be executed without blockchain. However, VisaNet is an exceptional example of the cost.¹⁷⁶

¹⁷¹ <https://dailyalts.com/blockchain-based-tokenization-could-revolutionize-alternatives-report/>

¹⁷² <https://searchcio.techtargt.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁷³ <https://searchcio.techtargt.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁷⁴ <https://www.cnbc18.com/cryptocurrency/solana-wall-street-darling-facing-turbulent-times-14569872.htm>

¹⁷⁵ <https://searchcio.techtargt.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁷⁶ <https://www.cnbc18.com/cryptocurrency/solana-wall-street-darling-facing-turbulent-times-14569872.htm>

b. Centralized ledgers

Centralized ledgers like Amazon’s Quantum Ledger Database¹⁷⁷ provides a shared database designed for ledger-like applications that provides a cryptographically verifiable audit trail without a distributed ledger or blockchain. Despite this, the ledger provides customers critical features offered by blockchain like immutability and verifiability, in addition to the ease and scalability provided by a traditional cloud service. However, Amazon has apparently admitted and cautioned that a proper blockchain could be a better alternative in case of untrusted parties.¹⁷⁸ Furthermore, both centralized databases and ledgers have points of failure that are prone to cybersecurity concerns and data breaches.

c. Distributed databases

Oracle and Microsoft also offer distributed databases that provide blockchain-like services including data replication and duplication to ensure data consistency and integrity. Platforms like OrbitDB open-source project support the creation of distributed, peer-to-peer operations without blockchain. These features enable companies to develop decentralized applications that run even without internet access and later sync up with other database nodes when reconnected. In addition to ensuring privacy and transparency, OrbitDB also allows operation if one node goes down, like blockchains.

d. Cloud storage

While decentralized blockchain storage is efficient, it is very costly. One megabyte of data on the Ethereum network could cost \$13,820, in comparison to a few cents charged by the Amazon Simple Storage Service (S3).¹⁷⁹ In certain cases, third-party cloud storage could also provide better governance and security than that offered by blockchain.¹⁸⁰

e. Decentralized storage

Decentralized storage platforms like Storj and the InterPlanetary File System (IPFS) promise distributed storage technology solutions allowing developers to encrypt files, split them into pieces, and distribute them across a global cloud network. Storj is also compatible with Amazon S3 storage tools to weave applications without learning new tools. Other ledger technologies like Iota Tangle, Hashgraph, and R3 Corda have also been identified as suitable alternatives to blockchain technologies. The use of decentralized storage potentially offers millions of nodes for hosting data availing a greater amount of storage. This can significantly reduce costs compared to centralized cloud storage platforms.¹⁸¹ As of October 2022, the European Union has emerged as a front-runner by proposing for decentralized data storage for the contents of the “personal digital wallet” including credit card data, driver’s license and medical prescriptions exclusively on the holder’s personal device, unless the holder requests for external

¹⁷⁷ <https://aws.amazon.com/qldb/>

¹⁷⁸ <https://searchcio.techtarget.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁷⁹ <https://searchcio.techtarget.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁸⁰ <https://searchcio.techtarget.com/feature/6-alternatives-to-blockchain-for-businesses-to-consider>

¹⁸¹ <https://medium.com/@ppio/why-ppio-can-achieve-a-lower-price-than-cloud-services-like-aws-b6ee89687a55>

backup and data storage.¹⁸²¹⁸³ This proposal is a part of the planned “European Digital Identity” that intends to give EU citizens greater access to public and private digital services including online payment facilities.

Despite its benefits, the use of decentralized cross-border data exchange is severely limited as a result of legal uncertainty on ‘anonymous’ data sharing in most jurisdictions.¹⁸⁴

¹⁸² <https://www.patrick-breyer.de/en/european-digital-identity-eu-parliament-wants-decentralized-data-storage-and-right-to-anonymity/>

¹⁸³ https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/LIBE/DV/2022/10-10/FINAL221006compromiseselDASLIBEopinion_EN.pdf

¹⁸⁴ <https://abovethelaw.com/2022/08/decentralized-autonomous-organizations-legal-implications-of-an-emerging-trend/>

9. Conclusion and key takeaways

Blockchain technology has the potential to deliver a wide range of benefits through its ability to enforce trust in a trustless environment. As discussed previously, these benefits include lower transaction costs, better transparency, enhanced liquidity, access to alternative sources of capital, increased transaction efficiency and less counterparty risk through decentralization.¹⁸⁵

The exponential growth of cryptocurrencies and tokens demonstrates there is an increasing acceptance of this new asset class, and the benefits of this technology are more and more recognized among financial market participants. At the same time, it is important to make the distinction between crypto as an asset class and tokenized securities. In the case of the latter, which is the focus of this paper, blockchain only serves as a digital vehicle or technological enabler. A tokenized equity or tokenized debt have similar financial characteristics and are regulated the same way as their traditional “off-chain” equivalents.

As tokenized securities also exist outside of the blockchain, they cannot be considered “blockchain native” like cryptocurrencies. This means there is an inherent limitation on how much tokenized securities can realize the benefits of this technology as the on-chain tokens need to be closely aligned with their off-chain components, while being compliant with a regulatory regime that was designed for securities issued and transacted on traditional financial markets.

Regulation, or rather the lack of regulation designed for tokenized securities, is the main barrier to using blockchain for infrastructure finance. The extent to which national security regulations accommodate tokenization can vary significantly across jurisdictions. As pointed out earlier, while there has been some notable progress in a few countries, there is still a lot of work to be done on the regulatory front before the full potential of tokenized securities can be realized.

One of the main challenges is how to minimize, or avoid altogether, the need to have off-chain components to make tokenized securities regulatory compliant. While it varies across jurisdictions, often some form of an off-chain structure is needed for the reconciliation with shareholder registries and to have the possibility of enforcing ownership and property rights, among other areas.

Another challenge is how tokenization can deliver on its value proposition to democratize finance, while complying with securities regulation. Indeed, it has the potential to provide access to a wider range of investors, including retail, to asset classes that were traditionally off limits. Investors seeking to have exposure to infrastructure normally have to become limited partners (LPs) in private equity or debt funds. However, due to their large minimum ticket sizes (over \$1 million), these funds are only a viable option for high-net-worth individuals (HNWI) or institutional investors.

¹⁸⁵ <https://www.iisd.org/system/files/publications/tokenization-infrastructure-blockchain-solution.pdf>

Tokenization can decrease these minimum sizes significantly, while making these investments more liquid. At the same time, many of the infrastructure tokenization projects to date were only accessible for accredited investors due to securities regulation. While the requirements differ across jurisdictions, generally becoming an accredited investor is not a possibility for retail investors. This is another area where financial regulation needs to evolve to better accommodate this new technology, otherwise tokenization cannot fulfil its promise to democratize investments.

As these examples also highlight, tokenization cannot deliver on many of its value propositions when it is fully compliant with relevant financial regulations, at least at the time of writing this report. However, we expect that blockchain, alongside other fintech solutions, will get more regulatory support in the years to come. We have already seen significant development in this area globally since 2018.

In light of this, should the World Bank further explore infrastructure tokenization? In the short term, we believe that the additional costs associated with setting up and launching a tokenization pilot are likely to cancel out any tangible benefits realized from tokenization. The question is rather, does the World Bank have an interest to use its position and influence as a leading development finance institution to support the wider adoption of this technology?

More specifically, the World Bank should consider tokenizing one of its infrastructure projects if it wants to pursue any of the following objectives:

1. Drive change in financial regulation to better accommodate the use of security tokens
2. Demonstrate leadership in the use of blockchain technology
3. Interact with the crypto ecosystem

1. Drive change in financial regulation to better accommodate the use of security tokens

Many companies active in the tokenization space have spent a significant amount of their resources to educate and work with regulators on how tokenized securities can be made regulatory compliant. We were told that this process can take a very long time and sometimes does not bring meaningful results. As tokenization is not a priority for most regulators, they do not have the incentives to commit the resources needed to drive change. On the other hand, companies in the space, usually still at the startup stage, simply do not have the necessary clout to get the attention of key decision makers and regulators. This is an area where the World Bank could make a difference by using its weight to highlight the need for more regulatory attention and help shape relevant financial regulation, alongside other stakeholders, to better accommodate the use of tokenized securities.

2. Demonstrate leadership in the use of blockchain technology

By launching a tokenization pilot, the World Bank can generate wider interest for the use of blockchain in infrastructure finance. A pilot would provide some reassurance to other DFIs and stakeholders in infrastructure finance that tokenization is indeed a viable technological alternative. This would encourage more pilots and experimentations, which would eventually make the whole ecosystem develop faster and become more efficient. It would also be a way to provide the necessary incentives for regulators across jurisdictions to focus on the space and provide more regulatory clarity on the tokenization of securities.

A pilot could also be a way to demonstrate the World Bank's willingness to innovate and experiment with new technologies. It is likely the Bank's previous endeavors in the space, such as the blockchain-based bond issue, had a similar objective. It would provide a strong signal to its peers and other financial market participants that despite being a 77-year-old organization, the World Bank is still ahead of the curve when it comes to innovation.

As a proof of concept, the World Bank is encouraged to tokenize projects that have a smaller ticket size in order to minimize the Bank's exposure to any additional risks arising from using this new technology. Alternatively, in case of a larger project, it is also possible to tokenize only part of the equity or debt financing used. If there is interest to create a secondary market for the tokens, projects with an attractive risk-return profile should be selected. Furthermore, they should be in sectors that a wider investor base would be familiar with and therefore comfortable to invest in, such as renewable energy. This could encourage the participation of investors beyond the traditional players in infrastructure financing, enabling infrastructure tokens to deliver on their promise to democratize the asset class.

The pilot should be located in a jurisdiction that has an accommodating regulatory framework for digital assets and tokens. As discussed in the section on regulation, these are typically developed countries, while the World Bank is active in emerging and developing countries. This inherent mismatch could be overcome by creating an SPV in a jurisdiction favorable to digital assets. The SPV would own the infrastructure project in one of the Bank's target countries, while the equity or debt financing of the SPV would be tokenized.

3. Interact with the crypto ecosystem

With a valuation of around \$3 trillion,¹⁸⁶ the crypto ecosystem represents a large capital pool that should not be ignored. Through a tokenization pilot, the World Bank would have the opportunity to interact with this crypto and token economy. This "interaction" can take various forms:

- a. Through its infrastructure tokens, the World Bank could tap the crypto capital pool to raise financing for its infrastructure project. This could potentially come at a lower cost than what

¹⁸⁶ <https://www.bloomberg.com/news/articles/2021-11-08/crypto-world-hits-3-trillion-market-cap-as-ether-bitcoin-gain>

would otherwise be the case. A new security token from a high-profile issuer, such as the World Bank, could generate significant demand from investors.

- b. Decentralized finance (DeFi) has grown exponentially in recent years, reaching \$200 billion on the Ethereum blockchain alone.¹⁸⁷ As discussed earlier, DeFi applications can provide basic financial services, like lending, without an intermediary. An asset-backed infrastructure token can open up a range of possibilities in the DeFi space. For example, lending protocols usually take various cryptocurrencies as collateral for loans. What if a token backed by an actual real asset would be used as collateral? How would that change the maximum amount a borrower could raise for the same value of tokens? If asset-backed tokens are treated significantly better, how would this impact the demand for tokenized securities? These are just a few examples when interacting with the DeFi side of the crypto economy could be beneficial for the World Bank.

Decentralized Finance (DeFi).¹⁸⁸

DeFi is a collective term used to describe financial products and services that are accessible to anyone who has access to the internet. DeFi eliminates the involvement of centralized authorities having the ability to block payments or deny any decisions. Services that were previously slow and subject to human error are now automatic and safer as they are operated by code and open to inspection and scrutiny.

- c. As earlier projects demonstrate, especially during the initial coin offering (ICO) craze, community building is an important aspect of the crypto ecosystem economy. This could be a worthwhile value proposition in the context of infrastructure tokenization as well. Building a virtual community of token holders could be a way for the World Bank to secure the support of various stakeholder groups, including local communities or the actual users of the infrastructure. It can also be a way to crowdsource any additional financing needed for the project later in its lifecycle, such as large one-off maintenance expenses or retrofits.

When the World Bank issued the world's first green bond in 2008, the issuance probably cost more than the traditional alternative. However, that transaction created the blueprint for today's sustainable bond market that has grown exponentially over the years, reaching the issuance of \$1 trillion in 2021 alone.¹⁸⁹ That green bond defined what should be the eligibility criteria for the use of proceeds and what to include in an impact report. It also provided a new model on how different stakeholders, such as investors, DFIs,

¹⁸⁷ <https://markets.businessinsider.com/news/currencies/defi-growth-ethereum-mainstream-adoption-jpmorgan-decentralized-finance-2021-11>

¹⁸⁸ <https://ethereum.org/en/defi/>

¹⁸⁹ https://assets.website-files.com/5df9172583d7eec04960799a/61786e26cde36b7570c6ae62_bx9570_Q3%20SF%20report_26Oct2021.pdf

and scientists, could collaborate on a new bond issue. It also formed the basis for the ICMA Green Bond Principles that is still being used today by the large majority of green bond issuances.¹⁹⁰

This is where the opportunity lies in the context of infrastructure tokenization. The decision whether the World Bank should explore this technological solution further should not be made based on the expected short-term benefits of a pilot. Instead, the question is what the Bank's long-term aspirations are in paving the way for the wider use of blockchain technology in the financing of infrastructure.

¹⁹⁰ <https://www.worldbank.org/en/news/immersive-story/2019/03/18/10-years-of-green-bonds-creating-the-blueprint-for-sustainability-across-capital-markets>

