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Towards Inclusive and Sustainable Infrastructure Development through Blockchain-enabled Asset Tokenization: An Exploratory Case Study

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Abstract. Infrastructure development is a key to supporting the economy and building social resilience. Unfortunately, existing infrastructure financing models struggle with multiple issues to close the widening financial gap and integrate environmental, social, and governance (ESG) factors to improve resilience and achieve sustainable growth. With the emergence of innovative technology, blockchain-enabled asset tokenization shows the potential to create a new economic model to integrate non-financial values, such as positive social and environmental impacts, into tradable cryptographic tokens. Tokenization offers opportunities to generate long-term positive social and environmental impacts, along with better financial returns, which further improves the profitability and bankability of infrastructure projects. SolarCoin, WePower Token, and ZiyenCoin are analyzed in this exploratory case study research to demonstrate how blockchain-enabled asset tokenization can be applied to infrastructure development. It is identified that tokenization promotes inclusiveness and sustainability through shareholder empowerment, incentive monetization, and finance optimization. Obstacles hindering the broader adoption of tokenization and policy implications are also discussed.

1. Introduction

Infrastructure is fundamental to social development and economic growth through creating connections, enabling communications, powering communities, and creating opportunities for every member of society. From power generation facilities to transport systems and water networks, infrastructure provides essential services enabling society to function and the economy to thrive. Infrastructure plays a vital role in making positive environmental impacts and strengthening inclusiveness and sustainability [1]. Quality investment in infrastructure is one of the main drivers for contributing to the United Nations Sustainable Development Goals (SDGs). However, the mismatch between the need for more and better infrastructure and the available financing continues to increase. An analysis by the McKinsey Global Institute forecasted that the world was facing a \$3.7 trillion gap between projected investment and the amount needed to provide adequate global infrastructure through 2035 [2]. Under the current financing system, public sector finance through direct grants, subsidies, and concessionary loans are subject to public budget constraints and political influence, which is unsustainable in the long run. Private



investment in infrastructure is limited to a narrow set of institutional investors such as pension funds and insurance companies, thereby leaving a significant amount of capital and resources on the sidelines. The current debt-dominated infrastructure financing system struggles with integrating environmental, social, and governance (ESG) considerations or providing incentives to promote SDGs. The COVID-19 pandemic has made the already difficult situation even more challenging. Pioneering thinking and a groundbreaking financing system are required to ameliorate public sector engagement and mobilize private sources from a broad spectrum to bridge the widening infrastructure gap and realize inclusive and sustainable growth to impact society and the environment positively.

Innovations are emerging at a swift pace in the information age, which offers the potential to transform the infrastructure system and its financing options more intelligent, efficient, and resilient. Blockchain is considered the most significant technological breakthrough since the internet. Blockchain is a type of distributed ledger for maintaining a permanent and tamper-proof record of transaction-based data. With the advancements in the blockchain, a decentralized, immutable, and trusted system can be built, which brings improved security, transparency, and automation. Building on the blockchain, asset tokenization enables the transition of assets in conventional forms into cryptographic tokens. Tokenization can introduce a new system to finance infrastructure in a more efficient, inclusive, and sustainable way [3].

Despite the aforementioned potential benefits and growing attention from media sources and practitioners, the field of infrastructure asset tokenization has not attracted comparable academic interest. It lacks a deeper grounding in theoretical and empirical analysis. This research aims to broaden current knowledge of infrastructure asset tokenization to deepen the understanding of how tokenization is applied to finance infrastructure while promoting inclusiveness and sustainability. So that infrastructure can better serve the surrounding community and the broader society. A detailed explanation of the potential benefits brought by infrastructure asset tokenization is outlined in Section 2. Use cases are analyzed in Section 3. Key research findings and recommendations for future research are included in the final section.

2. Infrastructure asset tokenization

Tokenization is the process of digitally representing existing assets on a distributed ledger, such as the blockchain. Asset tokenization enables the representation of assets on the ledger by linking or embedding the economic value and rights derived from the underlying assets into cryptographic tokens created on the blockchain [4]. Cryptographic tokens represent programmable assets or access rights, such as shares in a company, ownership of a piece of real estate, permissions to a platform, or electricity produced by energy plants. In theory, any asset and associated rights can be tokenized and represented on the blockchain. Tokens are categorized into three classes depending on functions and purposes [5].

- Payment tokens are a decentralized currency for making and receiving payments on the blockchain, such as Bitcoin. Payment tokens are used as an alternative means of exchange, supplement to fiat currency.
- Utility tokens grant access to products or services offered by the issuer of the tokens. This type of token is meant to be primarily used within the blockchain-based ecosystem. Utility tokens are issued through Initial Coin Offerings without the governance of existing security regulations in most jurisdictions.
- Security tokens are an investment instrument representing the legal ownership of a physical (e.g., real estate properties, gold, etc.) or digital asset (equity, bonds, loans, etc.) that has been verified within the blockchain. Issuance and transactions of security tokens are under the protection of existing security regulations.

Cryptographic tokens are governed and executed through smart contracts, which are software algorithms integrated into a blockchain with trigger actions based on pre-defined parameters. Smart contracts are

self-enforcing and self-executing. The automation reduces the administrative burden and the number of intermediaries required in the process, which leads to cost reduction and faster execution. Besides the efficiency gains brought by automation and disintermediation, tokenization delivers other benefits, including enhancing transparency, improving liquidity to currently illiquid assets (e.g., infrastructure assets), and enabling more efficient clearing and settlement [6].

Infrastructure asset tokenization refers to the process of tokenizing utilities (e.g., services or products provided by the underlying facility) or ownership interests of the conventional securities (e.g., equity of infrastructure companies or funds, loans, and bonds) onto the blockchain. Tokenization allows for the use of tokenized digital records in the infrastructure life cycle, from planning and financing to construction and operations. The crucial benefits related to the enhancement of inclusiveness and sustainability in infrastructure development by implementing tokenization are summarized into three categories: stakeholder empowerment, incentive monetization, and finance optimization [7].

- Stakeholder empowerment
 - Tokenization provides communities with a new tool of governance. Tokens embedded with certain rights of the infrastructure facility can be distributed to neighbouring residents, who serve as special shareholders to influence the planning and operations of the project through voting enabled by smart contracts. Consumerization through tokenization thus has the capacity to create a sense of local ownership of the public infrastructure facilities and provides a platform to galvanize social acceptance. By owning tokenized revenue-generating infrastructure assets, neighbouring residents can enjoy the social spill-over effects brought by the new infrastructure facility as well as receive an additional source of income.
 - Through tokenization, operational and financial information of the underlying infrastructure facility is automatically recorded on the blockchain immutably. The improved quality and quantity of operational and financial data will grant stakeholders and investors direct access to monitoring the project.
 - From investors' perspective, tokenization democratizes infrastructure assets and allows for fractional ownership, which lowers barriers to investment and promotes inclusiveness by offering financial access to individuals and small and medium-sized enterprises (SMEs). Tokens can also be distributed to the unbanked in the low-income community to address the inequality issue.
- Incentive monetization
 - Tokenization shows the capability to completely reinvent business models, create new economies and change society's view on earning income by converting non-financial values that can be monetized and traded across a blockchain, which incentivizes positive behaviors and efforts for sustainability. Tokens help stimulate the consumption of sustainable services and goods by providing financial incentives to users and customers and further improving the profitability and bankability of high-impact projects. Transactions on the blockchain are verified instantaneously. The instant incentives increase motivation even more.
- Finance Optimization
 - By deploying tokenization, the size of infrastructure projects is no longer a determining factor for financing cost efficiency. The disintermediation (removal of intermediaries) enabled by smart contracts, results in a significant fixed financing cost reduction and improved bankability of projects. Tokenization makes investment in small-scale infrastructure at the project level possible.
 - Smart contracts allow for bi-directional instant transfer of funds and tokens by removing intermediaries without the need for a separate settlement process. The automation enabled by smart contracts reduces the cost of transaction and administration, increases

the speed of execution, and facilitates dividend distribution, escrow management, and collateral management.

3. Case Study Analysis

This research employs an exploratory case study approach. Through case studies, a novel phenomenon and concept are better understood [8]. Given the novelty of infrastructure asset tokenization, multiple cases were studied to indicate how asset tokenization can be applied to promote inclusiveness and sustainability in the context of infrastructure development. Cases were retrieved from desk research. The selected cases depict the common features of infrastructure asset tokenization and also include adequate contextual and structural diversity. The use of multiple cases is based on the theoretical replication logic for producing contrasts in a cross-case manner [9].

3.1. Case A: SolarCoin

SolarCoin is a type of payment token designed to facilitate solar photovoltaic facility installation [10]. It was an open community project created in 2014 operated by the SolarCoin Foundation. The Foundation distributes SolarCoins to generators of solar electricity using verified solar facilities at the rate of one SolarCoin per one megawatt-hour (MWh) of solar energy produced. The SolarCoin blockchain is a trusted data layer reporting solar power production data, which provides a Know-Your-Device (KYD) anchor data provenance layer for providing more security when monitoring solar power produced. SolarCoins can be used as a means of rewards and payment. The value of SolarCoins is determined by the faith of its users in utility across the network, similar to Bitcoin. SolarCoins can be traded in the secondary market (e.g., Lykke) in exchange for other cryptocurrencies or fiat currencies.

In terms of shareholder empowerment, the immutable operation and performance data recorded on the SolarCoin blockchain grant stakeholders and investors direct access and visibility in the project's performance. Furthermore, the broader SolarCoin community can provide essential support to assist smaller projects initiated by SMEs and solar energy producers in developing countries to facilitate business growth in this sector. From the perspective of incentive monetization, SolarCoins, serving as direct incentives to reward solar energy producers, encourages the development of solar infrastructure facilities and the transition to clean and renewable energy. However, according to the Coinmarketcap, the market capitalization of SolarCoin fluctuated within the range between one million to five million dollars in the past year. As a currency with small market capitalization, its capability to realize the proposed goal is limited. The most significant obstacle faced by SolarCoins is to gain mainstream acceptance, incentivize communities to transition to solar energy, and convince power producers to share generation data. The promotion of SolarCoins depends on its liquidity and consumer attractiveness as compared to other cryptocurrencies.

3.2. Case B. WePower

WePower Smart Energy Tokens are utility tokens issued by WePower, a renewable energy procurement and trading platform that aims at facilitating the global shift to renewable energy by democratizing the energy procurement process [11]. Smart Energy Tokens represent fractional ownership rights and obligations obtained under power purchasing agreement (PPA) contracts. The tokens are exchanged among owners through auctions. The WePower platform applies smart contracts to execute transactions and connects energy producers and purchasers directly in a frictionless and secure manner. Information is stored on the Ethereum blockchain and available for participants to monitor auctions, transactions, and executions.

By applying blockchain-enabled tokenization, WePower Smart Energy Tokens backed by the fractional ownership rights of PPA simplifies the contracting process and enables individuals and companies, regardless of the size, to be engaged in renewable transactions transparently. In terms of financial optimization, the tokens allow energy producers to access a new segment of energy purchasers

at a lower cost. Energy producers can also contract with multiple purchasers at the same time, thereby diversifying their counterparty risk. For projects seeking finance, these features make new renewable infrastructure projects more bankable, thus potentially leading to the delivery of more renewable projects. The more cost-effective and transparent contracting and transaction process would encourage more energy producers and purchasers to transit to renewables and further facilitate sustainable infrastructure development. While bypassing the traditional project financing process in securing funding for projects is attractive, the disclosure of consumption and production data in the energy markets may be limited depending on the jurisdiction.

3.3. Case C. ZiyenCoin

ZiyenCoins are security tokens issued by Ziyen Energy, a pioneering tokenization company offering a total of 500 million equity-based security tokens backed by energy assets in its portfolio. The price of one ZiyenCoin is \$0.01. A maximum of \$5 million is planned to be raised with the security token offering (STO) to both U.S. and non-U.S. investors. The initial investment requirement is as low as 50,000 ZiyenCoins which is equivalent to \$500. The rights to the company's Class A securities, incorporation certificates, and bylaws are embedded into the smart contract of each ZiyenCoin. These rights are transferable in peer-to-peer (P2P) and secondary market trading. The company is acquiring more green energy projects facilitating the renewable energy transition [12].

The \$500 minimum initial investment requirement removes small investors' barriers to invest directly through small-value tokens to become shareholders of Ziyen Energy. Investors can invest in energy infrastructure assets in the U.S. and are able to build up a diversified portfolio based on their specific financial expectations. The advantage of blockchain in the information recording and storing grants investors and project stakeholders access to improved monitoring and management of their investments. The implementation of small contracts makes raising funds from the public markets possible for small-scale companies like Ziyen Energy, currently valued at \$5 million. This could significantly facilitate the development of SMEs and expedite the renewable energy transition. However, like many other early tokenization applications, ZiyenCoin is still evaluating its business model to scale market adoption and gain mainstream acceptance.

4. Conclusion

Three infrastructure-related tokenization cases are reviewed in this research. Cases were selected based on the type of cryptographic tokens. SolarCoins are payment tokens. ZiyenCoins and WePower tokens are security tokens and utility tokens, respectively. These cases indicate that various token models can be applied to facilitate infrastructure development and financing. The promotion of inclusiveness and sustainability is through shareholder empowerment (e.g., engaging the surrounding community, integrating high-quality data, and granting access to individual and SMEs), incentive monetization (e.g., monetizing non-financial values), and finance optimization (e.g., removing barriers to small projects and improving liquidity), relying on the blockchain and smart contracts. Three cases are all initiated by private entities in the energy sector, mainly owned by the private sector. No tokenization of public infrastructure cases was uncovered, indicating that public entities may be lagging in the early adoption of asset tokenization.

Three tokenization projects in this research are facing a common obstacle, which is high uncertainty at their early stage of development. SolarCoin was introduced in 2014, but it has not gained mainstream acceptance as planned when initiated. The structure of the WePower tokens was revised in 2019 after its initial launch in 2018. Information on these cases was extracted from whitepapers, which only demonstrates the business plans instead of actual operations. Due to the relative infancy of tokenization, there is minimal operational data available for in-depth analysis at present. Future research should conduct in-depth analysis based on data from operations to explicitly examine how tokenization

promotes inclusiveness and sustainability in the context of infrastructure development. The application of tokenization in other infrastructure sectors besides energy should also be studied.

Infrastructure asset tokenization shows the potential for facilitating infrastructure development while promoting inclusiveness and sustainability. A coordinated, proactive, and long-term approach that builds on existing practices by the public and private sectors is required to maximize the potential benefits brought by the emerging blockchain-enabled technology.

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