ADBI Working Paper Series

SCALING UP SUSTAINABLE INVESTMENT THROUGH BLOCKCHAIN-BASED PROJECT BONDS

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No. 1247
April 2021

Asian Development Bank Institute

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Suggested citation:

Chen, Y. and U. Volz. 2021. Scaling Up Sustainable Investment through Blockchain-Based Project Bonds. ADBI Working Paper 1247. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/scaling-sustainable-investment-blockchain-based-project-bonds

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We are grateful for very helpful comments and suggestions received from Ousmène Jacques Mandeng, Cyn-Young Park, Matthias Pelster, Peter Rosenkranz, Grace Tian, and other participants in the September 2020 conference "Fintech to Enable Development, Investment, Financial Inclusion, and Sustainability" organized by the Asian Development Bank, the Institute of Global Finance–University of New South Wales, the Asian Bureau of Finance and Economic Research, the National University of Singapore Business School, and the Asian Development Bank Institute; and the 33rd Australasian Finance and Banking Conference hosted by the University of New South Wales in December 2020. The usual disclaimer applies.

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Abstract

This paper explores options for mobilizing domestic savings through fintech solutions to scale up sustainable investment. Most developing and emerging economies face an urgent need to scale up sustainable finance for low-carbon and climate-resilient infrastructure investment, yet underdeveloped capital markets tend to inhibit domestic resource mobilization for infrastructure investment. At the same time, domestic savers in many developing and emerging economies face a scarcity of "safe" assets in the local currency, resulting in the exporting of capital to financial centers in advanced economies. The paper discusses how fintech can help to complement conventional capital markets and mobilize financial resources for sustainable infrastructure investments. It puts forward a proposal for blockchain-based project bonds to raise finance through a digital crowdfunding platform, which is also able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of projects by combining timestamp, public and private key mechanisms, and smart contract technologies. This approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment. It would also facilitate project management once the project is operational, for example through metering and billing, and create full transparency over the life cycle of the investment, reducing problems concerning the misuse of funds.

Keywords: sustainable investment, fintech, blockchain

JEL Classification: G23, O16, O18, Q01

Contents

1. INTRODUCTION

Countries all over the world are facing an urgent need to scale up their investments in sustainable infrastructure, including renewable energy infrastructure, to foster a low-carbon transition and to align their economies with the Paris Agreement and the 2030 Agenda. The International Monetary Fund (IMF) recently estimated the additional need for annual public investment in infrastructure, low-carbon technologies, and other areas to achieve the Sustainable Development Goals (SDGs) to be more than US$20 trillion over the next two decades (IMF 2020). Especially in developing and emerging economies, finance is a key challenge to the achievement of these investments. Although the international discourse on financing for development—under the catchy slogan "from billions to trillions"—has highlighted the need to unlock domestic resources, much of the discussion has centered on incentivizing private capital from advanced countries to finance investment in developing and emerging economies. While foreign aid and foreign private capital can play an important role in financing development, it is important to acknowledge the limits to the role of foreign investment in financing infrastructure and the financial vulnerability risks associated with foreign lending. It is also important to make better use of domestic savings in developing and emerging economies, many of which invest significant amounts of their savings in low-yielding assets in the financial centers of advanced economies. Strengthening domestic resource mobilization is therefore crucial, and concerted efforts to this effect are necessary. Besides the mobilization of finance, a central problem regarding infrastructure investment is corruption. The IMF (2020, 1) estimated that "one-third of funds for public infrastructure is lost worldwide to inefficiencies." It is hence crucial to identify ways to reduce this slack if not to eliminate it.

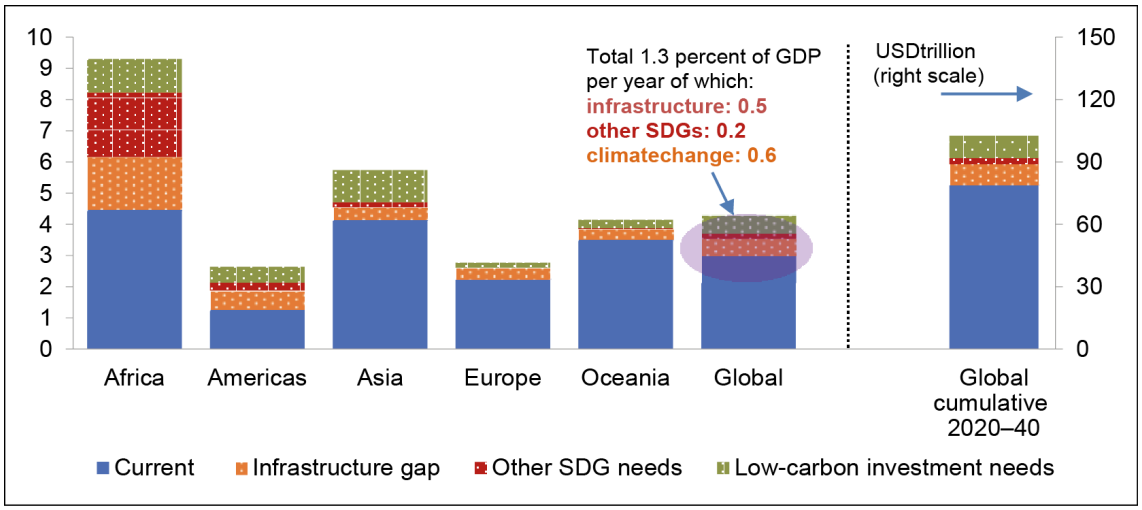
Against this backdrop, this paper will discuss how financial technologies—or fintech—and blockchain-based solutions can facilitate domestic resource mobilization for sustainable investments and at the same time improve the implementation of infrastructure projects throughout the entire life cycle by facilitating processes and enhancing transparency. In particular, the paper explores how fintech can help to complement conventional capital markets and mobilize financial resources for sustainable infrastructure investments. It proposes blockchain-based project bonds to raise finance through a digital crowdfunding platform, which is also able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of projects by combining timestamp, public and private key mechanisms, and smart contract technologies. This approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment. It would also facilitate project management once the project is operational, for example through metering and billing, and create full transparency across the life cycle of the investment, reducing problems involving the misuse of funds.

The structure of the remainder of the paper is as follows. Section 2 discusses the requirement to scale up domestic resources for the necessary investment in low-carbon, sustainable infrastructure and to meet other sustainable investment needs. It also examines the problems facing developing and emerging economies in mobilizing these resources locally for domestic investment. Section 3 then reviews the solutions for raising local savings and enhancing sustainable investment that fintech applications make possible, paying particular attention to blockchain solutions. Subsequently, Section 4 puts forward a proposal for an integrated blockchain-based fintech solution. Section 5 concludes.

2. DOMESTIC RESOURCE MOBILIZATION FOR SUSTAINABLE INVESTMENT

The IMF (2020) estimated the additional annual public investment needs in infrastructure, low-carbon technologies, and other areas to achieve the SDGs to be 1.3% of the world GDP (Figure 1). Cumulated over the period 2020–2040, the estimated additional investment needs would exceed US$20 trillion in current US dollars. To scale up finance for the SDGs, multilateral development banks (MDBs) have advanced the "billions to trillions" agenda to "unlock, leverage, and catalyze private flows and domestic resources" (African Development Bank et al. 2015, 2). The idea is to use official development assistance, or "blended finance," to mobilize private capital for investment in sustainable development.

Figure 1: Global Investment Needs for Infrastructure, Climate Change, and Other SDGs (Percentage of Annual Regional GDP; Trillions of US Dollars, Right Scale)



SDGs = Sustainable Development Goals.

Note: The blue bars show the current investment levels across regions as of the end of 2017. The estimates for additional global investment needs are, on average, 1.3% of the global GDP per year during the period 2020–40 (exceeding US$20 trillion in current US dollars) and comprise infrastructure (0.5% of the GDP), other SDGs (0.2% of the GDP), and low-carbon investment (0.6% of the GDP). The right panel shows the cumulative investment needs in trillions of US dollars (constant 2019 prices and exchange rates) over the next two decades.

Sources: IMF (2020), drawing on data from Global Infrastructure Hub; Oxford Economics; and IMF staff estimates.

Critics of blended finance have voiced concerns about the financial stability risks associated with "the escorting of international capital by multilateral development agencies into frontier and emerging market settings" (Carroll and Jarvis 2014, 540). A fundamental problem of initiatives aiming to leverage private investment by "de-risking" is that the risk itself does not disappear but merely shifts to public balance sheets (Mazzucato et al. 2018). In particular, critics have raised concerns that issues around the "complexity, accountability and transparency" of blended finance (Mawdsley 2018, 194) and the growing risks of related financial innovation and over-financialization in developing economies (Akyüz 2017) may contribute to debt crises. Financial stability risks may also arise from the fact that both development finance institutions and private financiers usually provide finance only in international currency, which leaves

borrowers with foreign exchange risk.[1] The United Nations Conference on Trade and Development (UNCTAD) (2019, viii) stated that "the focus of the development finance agenda on complex – and mostly non-transparent – new financial instruments and on securitized finance, does not bode well for its ability to deliver reliable financing at the required scale to where it is most needed."

Instead of trying to lure international capital for blended finance solutions—which has not been very successful to date, as the small volumes and low leverage ratios reflect (Attridge and Eigen 2019)—efforts should concentrate more on mobilizing domestic resources without creating complex financial structures. While foreign capital in the form of direct investment or foreign aid has played a role in the economic development of many countries, historically no economy has developed its infrastructure and financed its development primarily through foreign finance. Mobilizing domestic savings for local investments is hence a crucial part of economic development. The good news is that, for many countries, especially middle-income countries, domestic savings are not the main bottleneck.

In fact, many developing and emerging market economies, especially in Asia, are net capital exporters, as reflected in their current account surpluses. Even countries that do not record current account surpluses tend to invest parts of their savings at low or negative returns in the financial centers of advanced countries, only for these countries to reinvest them in their home countries, typically at higher returns, which then benefit the foreign investors. This phenomenon is known as round-tripping of capital. There are different reasons for investing domestic savings abroad, including macroeconomic instability at home, international portfolio diversification, and tax evasion. Two important reasons to invest savings abroad (which motivate this paper) are the better financial services abroad and the lack of safe financial assets in the domestic economy due to underdeveloped capital markets.

The reliance on foreign currency borrowing to finance domestic investment has been associated with two major problems: currency mismatches and maturity mismatches (Goldstein and Turner 2004). Financing long-term projects that yield returns in domestic currency with short-term foreign-currency credit creates financial vulnerabilities that can contribute to financial crises. The currency crisis literature has highlighted the importance of developing local-currency bond markets to overcome "original sin"—the problem that most emerging markets in the past were unable to borrow in domestic currency, even domestically (Eichengreen, Hausmann, and Panizza 2003)—and avoid the financial vulnerabilities associated with currency mismatches (Burger and Warnock 2006, 2007; Burger, Warnock, and Warnock 2012).

Since the emerging market crises of the late 1990s and early 2000s, countries have made progress in developing local-currency bond markets (Burger et al. 2012; Berensmann, Dafe, and Volz 2015; Dafe, Essers, and Volz 2018). Nevertheless, these are in part still highly dependent on foreign investors. The large-scale withdrawal of international capital from emerging economies' bond markets in March 2020 has once again highlighted the vulnerabilities associated with a shallow domestic investor base and heavy reliance on international portfolio investors (Beirne et al. 2020; Hofmann, Shim, and Shin 2020). There is clearly a need to develop local-currency capital markets further with a strong domestic investor base. An important question in this context is the following: can fintech help by mobilizing domestic savings and channeling them into sustainable investments?

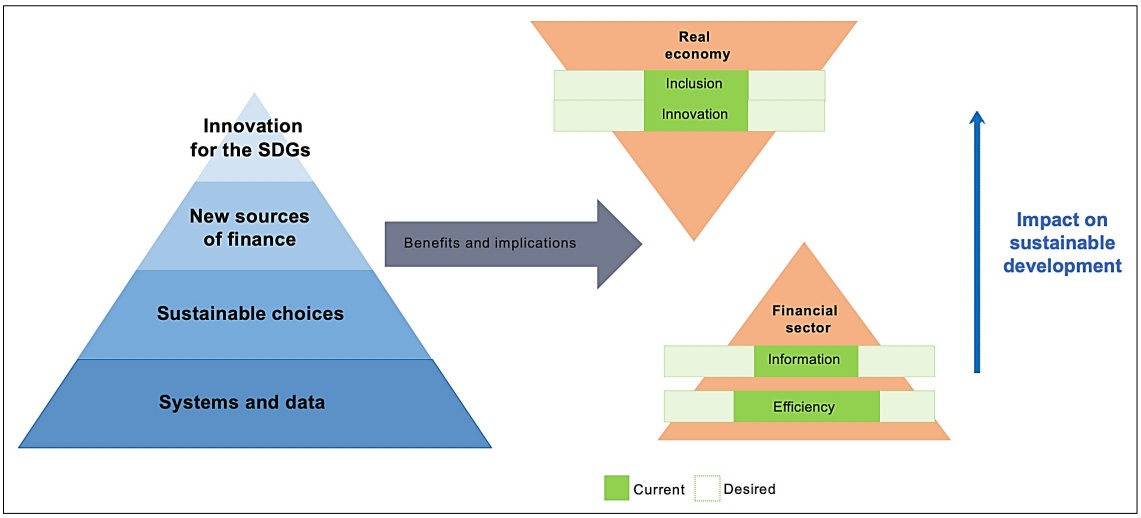
[1] For a discussion of the shortcomings of blended finance in leveraging private capital, see Attridge and Engen (2019).

3. FINTECH SOLUTIONS TO ENHANCE SUSTAINABLE INVESTMENT

3.1 Current State of the Discussion

Emerging financial technology has already had significant impact on financial development and holds great potential to advance the sustainable finance agenda (Chishti and Barberis 2016; Jeucken 2010). The G20 Sustainable Finance Study Group highlighted the emerging practice of applying digital technologies to sustainable finance (G20 SFSG 2018). As shown in Figure 2, the Sustainable Digital Finance Alliance (SDFA) identified several challenges to connecting the financial sector with the real economy and highlighted the potential of digital finance for improving information and efficiency in the financial sector through better systems and data and for fostering inclusion and innovation in the real economy by broadening sustainability choices and providing new sources of finance. It is possible to develop and apply digital technologies to leverage sustainable finance by facilitating better use of sustainability-related data for financial decision making and by supporting nascent business models by enabling better access to funding. Digital finance can help to address the barriers that limit the scalability of sustainable finance, such as the lack of local community power and asymmetrical information between investors and other stakeholders. Consequently, digital finance can help to promote goals such as financial inclusion and energy justice, both of which are key issues in the sustainable transition (Demirguc-Kunt et al. 2018; Aboushady and Gowaid 2019; Arner et al. 2020; Volz et al. 2020).

Figure 2: Implications of Digital Finance for Sustainable Development



Source: Authors' compilation based on SDFA (2018).

The UN Secretary General's Task Force on Digital Financing of the SDGs recently emphasized the development of financial inclusion into citizen-centric finance as one of the transformational opportunities that digitalization offers (Digital Financing Taskforce (DFTF) 2020). Citizen-centric finance is not only about the financial return but also represents an aggregation of influence through different channels and organizations (DFTF 2020).

Fintech or digital finance is a business approach dedicated to making financial services more efficient through internet-related technologies. Normally, fintech companies play two roles in the financial sector. One is as a challenger of traditional financial institutions, in which these fintech companies rely on algorithms or machine-based logic to replicate the back-office processes of traditional financial institutions and generate new technology-based business models. The other is as a pioneer in providing services in places where there is no traditional financial infrastructure, for example through mobile banking and other internet-based automated information platforms. Fintech comprises different applications, including lending, blockchain/ crypto, regtech, personal finance, payment service/billing, insurance, capital market solutions, wealth management, money transfer/remittances, and mortgage/real estate financing (Table 1).

Table 1: Overview of Fintech Solutions

Fintech Category	Examples
Lending solutions	Online marketplace lending and alternative underwriting platforms such as peer-to-peer lending platforms and digital crowdfunding platforms
Blockchain/crypto	Companies leveraging blockchain technologies for financial services
Regtech	Audit, risk, and regulatory compliance software
Personal finance	Tools to manage bills and track personal and/or credit accounts
Payment service/billing	Payment processing, payment transferring, card developers, and subscription billing software tools (a major function of mobile banking)
Insurance solutions	Online insurance services or data analytics and software for (re)insurers
Capital market solutions	Sales and trading, analysis, and infrastructure tools for financial institutions
Wealth management	Investment and wealth management platforms and analytical tools
Money transfer/remittances	International money transfer and tracking software
Mortgage/real estate financing	Mortgage lending and financing platforms

Source: Authors' compilation drawing from CB Insights (2019).

Countries have developed mobile banking further to provide investment opportunities in capital markets for people who would traditionally have neither the means nor the expertise and access to invest in securities. For instance, the M-Akiba project is a mobile-based fintech solution that the Government of Kenya has developed. The scheme focuses on local, small-scale individual investors and engages them to raise funds for national building (Central Bank of Kenya 2020a). In a similar project in Kenya, called Treasury Mobile Direct (TMD), the Central Bank of Kenya enabled users to buy treasury bills and bonds on their phone (Central Bank of Kenya 2020b). However, the value of these bonds and bills is questionable due to the abuse of government power in adjusting interest rates and potentially associated multiple transaction costs (Suri, Karlan, and Wayua 2018). Neither M-AKIBA nor TMD are based on blockchain, which allows the recording of each party's digital property rights and curbs corruption (Kshetri and Voas 2018).

Digital crowdfunding platforms can offer new solutions for personal finance and wealth management. For instance, digital crowdfunding platforms can mobilize financial power and accumulate local resources (Schwienbacher and Larralde 2012). Belleflamme, Omrani, and Peitz (2015) classified crowdfunding into two groups: investment-based crowdfunding (financial-based crowdfunding) and reward- and donation-based

crowdfunding (nonfinancial-based crowdfunding). The first category includes equity-based, royalties-based, and loan-based crowdfunding, in which the funders are investors in the campaign and may receive monetary gains through the growth of the company or based on the interest rate. In the second category, funders cannot expect to receive monetary compensation. They fund the campaign because they obtained the product or because they supported the purpose (or a combination of the two).

3.2 Blockchain

3.2.1 Technical Features and Value Added of Blockchain

Blockchain is an emerging technology that has attracted great attention from financial institutions, energy companies, technical developers, national governments, and academia (Hughes et al. 2019). Blockchain technology, which relies on distributed ledger technology (DLT), provides an encrypted, tamper-proof, and transparent system that can implement innovative business solutions by integrating or disrupting different business models. Zheng et al. (2018) summarized blockchain in four key characteristics, namely decentralization, network persistency, anonymity, and audibility. They also highlighted three challenges: scalability, privacy leakage, and selfish mining. Several reports, including Galen et al. (2018), Herweijer, Waughray, and Warren (2018), and Organisation for Economic Co-operation and Development (OECD) (2019), maintained that blockchain has the potential to bring significant innovation that can support the low-carbon transition.

DLT usually relies on a peer-to-peer (P2P) architecture with broadcast capabilities, recording transactions simultaneously in multiple locations. Generally, DLT systems allow computers to exchange information directly without going through a central server or an authorized institution (Lawrenz, Sharma, and Rausch 2019). The best-known DLT technology is blockchain, which usually uses a specific structure consisting of a chain of data blocks. People often use “blockchain” and “DLT” interchangeably.

3.2.2 Blockchain Applications in Financial Markets

In 2018, the World Bank launched a new type of bond, called Bond-*i*, which is a blockchain-operated new debt instrument. The bond raised US$100 million with a 2-year maturity and a triple-A rating (Klopfer 2018). In 2019, the World Bank raised an additional AUD50 million and expanded the market participation with the Bond-*i* platform (Reichelt 2019). The purpose of this bond is to exploit the potential of disruptive technology for faster, more efficient, and more secure transactions. It is not only advanced countries that are leveraging blockchain for bond development; emerging market players are also exploring this niche market. BMT Bina Ummah, an Indonesian Islamic microfinance cooperative, raised IDR710 million (US$50,000) through the world’s first issuance of Islamic bonds on a public blockchain (Gonçalves 2019). In Thailand, the Public Debt Management Office sold THB200 million saving bonds through Krungthai Bank’s blockchain-based e-wallet system to engage retail investors in the market (Bank of Thailand 2020).

Blockchain can play an important role in the green bond market. In the conventional bond market, it is hard for multiple stakeholders to monitor the flow of money, obtain or provide updates on the development status in real time, or demonstrate the impacts of green bonds (Banga 2019). The use of blockchain in the green bond market could help to enhance system transparency and capital traceability. The SDFA and HSBC (2019) indicated three directions for combining blockchain technology and the green bond market:

1. Building a blockchain-supported bond issuance platform, which could digitalize the whole bond-issuing process. This includes utilizing stablecoins—a digital form of money (or cryptocurrency) which is typically pegged to fiat money—for automatic settlement and payment to investors and for setting transparent nodes for supervision.[2]
2. Converting the manual reporting into data tokens, enabling investors to communicate in real time and establish a shared asset history on the ledger for the project aggregation.
3. Providing a "bond-as-a-service" platform to enlarge the local community bond market. This means that people can create their green bonds at low cost in the blockchain system and provide them in certain markets through security tokens. This will allow smaller entities (such as medium-sized companies or communities) to issue green bonds directly without the need for banks to provide expensive full services.

Apart from the traditional bond market, DLT is applicable as a new format of crowdfunding. Several papers have argued that blockchain has the potential to bring significant innovation to the crowdfunding sector and enhance financial inclusion (Zhu and Zhou 2016; Muneeza, Arshad, and Arifin 2018). Blockchain technology provides a distributed, tamper-proof, and encrypted system that can disrupt the traditional model of crowdfunding (Hartmann et al. 2019). For example, it could be possible to back renewable energy assets as cryptocurrencies.

Blockchain-based crowdfunding activities have similarities to conventional crowdfunding models but conceptualize the monetary value in token form, such as Initial Cryptoasset Offerings (ICOs) and Security Token Offerings (STOs) (Ackermann, Bock, and Bürger 2020). There are three types of blockchain-based crowdfunding models: utility token, payment token, and investment token (Howell, Niessner, and Yermack 2018). Utility tokens are the inherent carriers of value on the platform, protocol, or network that network participants need to hold to engage or access the products or services that the platform, protocol, or network provides (Hartmann et al. 2019). Utility token sales are similar to traditional reward-based crowdfunding models. Investment tokens such as security tokens bear more similarities to conventional equity-based crowdfunding. Payment tokens are similar to fiat money, especially in terms of stablecoins, which are typically pegged with fiat money.

Blockchain utilizes smart contracts to automate transactions and enhance reliability and efficiency (Peters and Panayi 2016). The code, which aims to list and add conditions on every possible transaction, can embed the legal elements (Clack, Bakshi, and Braine 2016). Transactions will happen automatically when all the network participants have agreed to the set terms. Studies have argued that a large portion of the population can benefit from blockchain technologies, especially in developing countries (Kshetri and Voas 2018). With the increasing affordability and usability of smartphones, blockchain can offer a better value proposition because of typically weak rules, laws, regulations and enforcement in developing countries and regions (Kshetri and Voas 2018).

In an interesting case study from the Yale Open Innovation Lab, blockchain initiated the financing of a decentralized energy resource (DER) platform called OpenSolar (Wainstein 2019). OpenSolar is a security-based (lending and equity) crowdfunding platform. Unlike a traditional public–private partnership project (which locks users or "off-takers" into a long-term payment agreement without final ownership), the project

[2] A stablecoin could be a digital currency that a central bank issues.

allows people to own the DERs in real time. Thus, they can participate in the local energy economy as co-owners of community-based microgrids. However, the scalability of such projects is still an issue. Other channels are necessary to scale up such projects, such as offering user-friendly applications to mobilize finance for infrastructure projects. For instance, mobile phone applications—such as those that M-AKIBA or TMD use— could help to provide an investment opportunity for people to buy these assets and a platform for people to invest in rights to benefit from the local energy infrastructure.

3.2.3 Blockchain Applications in Industries

In the context of energy, climate, and the environment, blockchain applications in the energy industry mainly include the following: 1) cryptocurrencies for funding renewable energy projects; 2) metering, billing, and security; 3) decentralized energy trading; 4) green certificates and carbon trading; 5) grid management; 6) Internet of Things (IoT), smart devices, automation, and asset management; 7) electric e-mobility; and 8) general-purpose initiatives developing underpinning technology (Andoni et al. 2019).

In the context of decentralized energy trading schemes, several applications are in the early stages of development: wholesale energy trading, energy trading support for small generators and end-consumers, energy trading for utilities and energy system stakeholders, and P2P trading in community projects and microgrids (Andoni et al. 2019). Although the scale of their adoption is limited at this stage, these applications have the potential to create radical changes that would disrupt the incumbent business model of energy suppliers or grid operators that have the monopoly power or own the physical infrastructure. The potential impact of emerging localized or community-based energy systems on the mainstream energy system, and the role of blockchain in this transition, remains to be seen. The way in which blockchain interacts with regulation, policy, and markets to deliver certain promises for end users needs further investigation.

Blockchain is able to connect the energy and financial systems. For example, blockchain could finance local energy projects and, in the subsequent operational phase of the utility, work with IoT to collect metering and billing data, ensuring the certification of origin. In the following, we develop a proposal that combines different fintech- and blockchain-based approaches that countries could employ to mobilize domestic savings to finance and operate local energy projects.

4. A PROPOSAL FOR A BLOCKCHAIN-BASED BOND FOR SUSTAINABLE INVESTMENTS

We propose a comprehensive blockchain-based approach that integrates multiple fintech applications to mobilize domestic financing for sustainable infrastructure investment. The approach should account for the interests of the various stakeholders involved, including local residents, public policy, multiple investors, and possibly international development agencies. Table 2 provides an overview of the likely interests of these stakeholders.

Table 2: Main Interests of Stakeholders

From a Public Policy Perspective
Investment in sustainable infrastructure to support local development
• Deliver and operate infrastructure utilities at low cost, with a reliable revenue stream
Favorable financing conditions
• Raise long-term project finance in the domestic currency and avoid currency and maturity mismatches • Low interest rates
Financial sector development and reduction of financial instability risk
• Strengthen domestic local-currency bond markets • Strengthen the local investor base • Broaden opportunities for investing domestic savings in safe assets
Strengthen accountability and "good governance"
• Strengthen the transparency of the use of proceeds and reduce corruption problems
From an Investor Perspective
Investment opportunity in "safe assets" (i.e., low risk of default) User-friendly investment process Easy access, even for small amounts for retail investors Aggregation of small-sized projects for institutional investors Sustainability-driven projects that qualify as impact investment Institutional quality/good governance practice Enhanced information transparency Avoiding greenwashing
From a Local Resident Perspective
Investment in sustainable infrastructure to support local development Access to quality infrastructure services at low cost No negative environmental externalities Positive local employment effects
From a Development Agency Perspective (If Applicable)
Support sustainable infrastructure development Promote access to affordable energy, water, etc. Promote "good governance"/anti-corruption efforts Support domestic financial market development

Source: Authors' compilation.

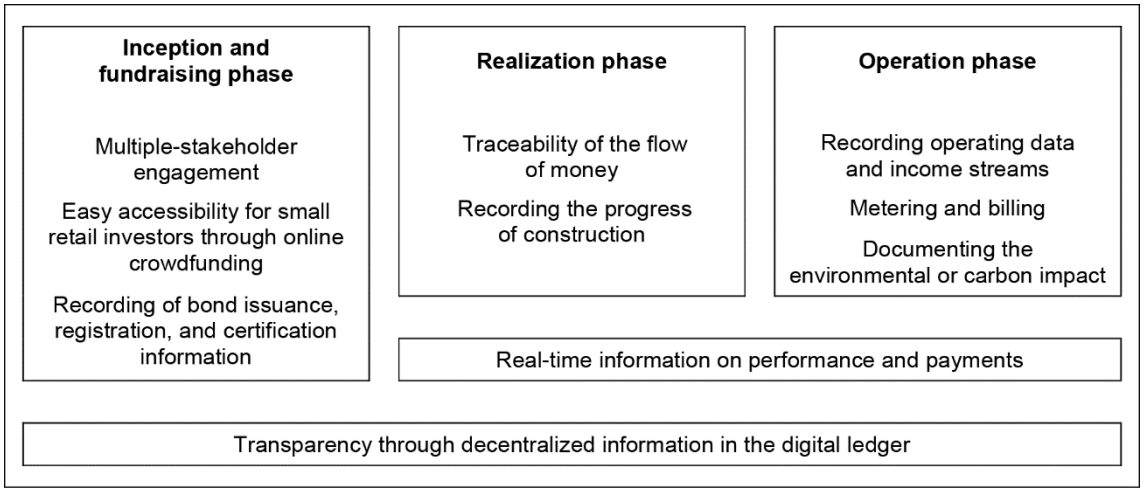
Our proposal would address these stakeholder interests. Moreover, it would help to tackle major concerns in the three key phases of an infrastructure project's life cycle: the inception and fundraising phase, the realization phase, and the operation phase (Figure 3). First, in the inception and fundraising phase, blockchain applies the crowdfunding logic to mobilize domestic savings for investment in the domestic local-currency bond currency market. The ledger can record the ownership structure to ensure customers' user rights. As the above cases show, fintech applications, such as M-Akiba and TMD, could be used to mobilize local savings for the domestic bond or bill market, allowing for small-size investments through easy-to-use online applications. However, transparency concerns and inflexible investment methods can hold back investments. Applying smart contracts can reduce problems of asymmetric information risk. By applying blockchain technologies, such as timestamp[3] as well as public and private key mechanisms,[4] the bond-issuing entity can record the bond issuance, registration, and certification information in the blockchain network, augmenting the

[3] A timestamp is coded information identifying when a specific event occurs, usually providing the date and time.

[4] The public and private key mechanism is an encryption system that uses a pair of keys: a public key that can be widespread and a private key that only the owner knows.

credibility of projects. By integrating crowdfunding and the local-currency bond market, blockchain can enhance the efficiency of the fundraising phase by engaging with multiple stakeholders and promoting accessibility.

Figure 3: Key Phases of the Infrastructure Project Life Cycle and Advantages of a Blockchain-Based Finance Approach



Source: Authors' compilation.

Second, in the realization phase, all stakeholders can trace the use of proceeds and obtain information on the construction status in a transparent way. By ensuring investors' ownership, the issuing entity can collect funds from domestic customers and generate more sustainable projects. As mentioned above, one incentive to track financial flows with blockchain is that digitization can have a dampening effect on corruption. Investors face the risk that the issuing entities may misuse the funds and never return the investment. By recording information on the flow of money during the construction phase through blockchain, investors can better understand the status of the project and decide whether they will continue to devote money to the project. If the money that the issuance raises is misused or the project realization stalls, investors can take decisions with near real-time information. Smart contracts should format and automate the interest rate and return.

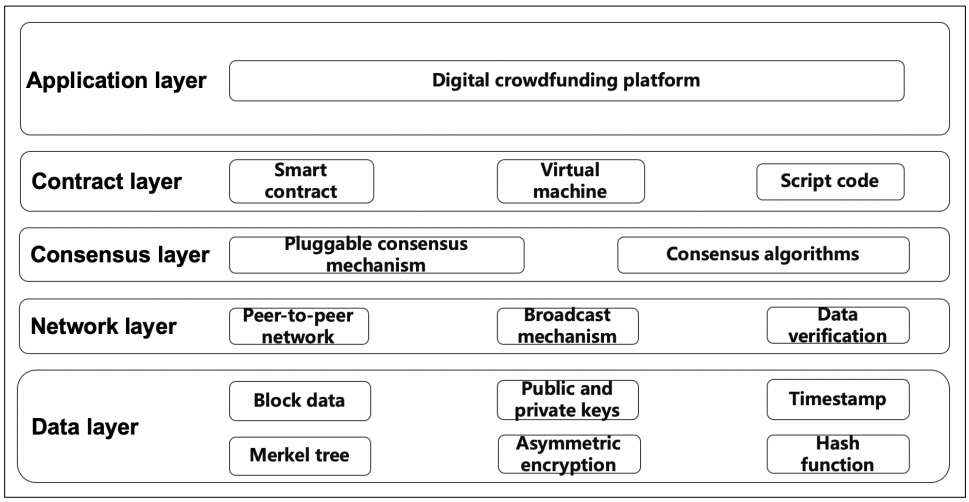
Third, blockchain cannot only be employed to finance an infrastructure project transparently but it could also help to manage the project when it is operational, for example through metering and billing applications. Downes and Reed (2020) showed that transparency should comprise three parts: evidence, disclosure, and access. "Evidence" refers to a record of relevant information, such as green certification for renewable energy or carbon credits. "Disclosure" means that the project operator should provide multiple stakeholders with information so that they can monitor and verify the operation process. "Access" means that stakeholders should have the right to access information to evaluate the operating status and decide whether to stay invested. By recording operating data with blockchain, stakeholders can receive transparent information on project revenue streams and reduce the risk that investors will receive no returns because a corrupt manager has absconded with the money. The whole data life cycle management offers a new way to raise funds for sustainable investment.

An example would be a community-based renewable energy project, in which investors can also play the role of consumers. A community ownership model would allow a "pay-as-you-go" approach, whereby the developers are the utility companies that sell, for example, electricity services through a pre-paid model. By recording the investor profile in the blockchain network, consumers can leverage their ownership of the project to use electricity and even trade with each other, that is, to become "prosumers"—producers and consumers at the same time. This is a suitable solution for adopting a net metering policy for microgrid or other renewable projects, enabling investors to become prosumers (Stoutenborough and Beverlin 2008; Hwang et al. 2017).

Blockchain also provides the option of documenting the environmental or carbon impact, which could, for example, enable the receiving of carbon credits through carbon emission trading schemes. The issuing entity can leverage blockchain to build an impact investing information platform, which incentivizes asset managers and customers in the space by quantifying the carbon certification or emission reductions, or any other positive impacts—be they ecological or social—that the project may have. Automated proof-of-impact reporting can deliver near real-time information on the sustainability impact, providing investors with assurance on the "greenness" or sustainability of their investment.

It is possible to configure our proposal in multiple ways to suit different situations. The main goal of this proposal is to leverage the strength of a decentralized governance model with the support of blockchain to achieve project-level financial inclusion. Through the blockchain-based project development platform, the issuing entity can engage with retail investors who would like to own parts of the project, such as a micro-grid project, by equity crowdfunding. Retail investors may receive deductions on their utility bill as part of their bond interests. Furthermore, by replicating this approach, it would be possible to aggregate multiple projects to create a larger portfolio that would be attractive to institutional investors, including impact investors.

Figure 4: Technical Structure of the Proposal



Source: Authors' compilation.

Figure 4 illustrates the different layers and elements of the technical side of our proposal. This figure includes a digital crowdfunding platform for the funding as the main application in our proposal; technological features such as timestamp, public and

private key mechanisms, smart contract, and other technologies that we mentioned in the text are part of the blockchain network. These technological features enable the process of registration and certification in the blockchain network and data life cycle management for using blockchain to mobilize information on (i) the use of proceeds, (ii) the construction/realization of the project, (iii) the operation of the project and its environmental/social impact, (iv) metering/billing, and (v) revenue streams.

5. CONCLUSION

In this paper, we explore how fintech can complement conventional capital markets and help to mobilize finance for sustainable infrastructure investments. Based on an analysis of the interests of relevant stakeholders, it puts forward a proposal for blockchain-based project bonds aiming to finance sustainable investments. It involves the use of a digital crowdfunding platform to raise finance, while the blockchain is able to record transparently and certify the use of proceeds, sustainability impact, and revenue streams of the project. The suggested approach would not only provide investors of different sizes with the opportunity to purchase local-currency assets and issuers such as municipalities to raise funds for sustainable infrastructure investment. It would also facilitate project management once the project is operational by offering easy technical solutions for metering and billing. Last but not least, this approach would create full transparency across the life cycle of the investment, reducing problems of misappropriation of funds. This in turn should increase the attractiveness of the underlying project.

Municipalities, for instance, could issue the proposed blockchain-based project bonds to finance local infrastructure, such as energy utilities, that would generate returns that they could use for payments of coupon and principal. Multiple applications to suit different situations would be possible, including community ownership structures, using the strength of a decentralized governance model with the backing of blockchain. While this approach is applicable to smaller investments, it would also be possible to aggregate smaller assets into bonds that would also be of interest to larger institutional investors. Development finance institutions could play an important role in implementing such investments. Through their involvement, they could also enhance the confidence of potential investors.

To our knowledge, such an approach remains unexplored in practice. With support from the UNDP and UNCDF, the UN Secretary General's Task Force on Digital Financing of the SDGs has recently launched a Pathfinder Initiative with the Government of Bangladesh to explore how to use digital technology to mobilize small amounts of domestic savings for sustainable infrastructure investment (LightCastle Partners 2020). Very much in line with our proposal, this initiative envisages the transformation of micro savers into micro investors and the reduction of the need for international borrowing, using blockchain as a technical backbone to improve the accountability of the funds and returning the dividends from infrastructure investment to the Bangladeshi citizens (LightCastle Partners 2020). Going forward, it would be desirable to develop similar pilots and integrate some features of our proposal to gain operational experience with a view to scaling this up to mobilize much-needed investment in sustainable infrastructure.

REFERENCES

Aboushady, Ahmed, and Azmy I. Gowaid. 2019. “Small Scale Renewable Generation Unlocking an Era of Peer-to-Peer Energy Trading and Internet of Energy.” *Renewable Energy and Sustainable Development* 5 (1): 1–2.

Ackermann, Erik, Carolin Bock, and Robin Bürger. 2020. “Democratising Entrepreneurial Finance: The Impact of Crowdfunding and Initial Coin Offerings (ICOs).” In Alexandra Moritz, Joern H. Block, Stephan Golla, and Arndt Werner, eds., *Contemporary Developments in Entrepreneurial Finance. An Academic and Policy Lens on the Status-Quo, Challenges and Trends*: 277–308. New York: Springer.

African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, International Monetary Fund, and World Bank Group. 2015. *From Billions to Trillions: Transforming Development Finance Post-2015. Financing for Development: Multilateral Development Finance*. Development Committee Discussion Note. Washington, DC: World Bank and International Monetary Fund.

Akyüz, Yilmaz. 2017. *Playing with Fire. Deepened Financial Integration and Changing Vulnerabilities of the Global South*. Oxford: Oxford University Press.

Andoni, Merlinda, Valentin Robu, David Flynn, Simone Abram, Dale Geach, David Jenkins, Peter McCallum, and Andrew Peacock. 2019. “Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities.” *Renewable and Sustainable Energy Reviews* 100: 143–74.

Arner, Douglas W., Ross P. Buckley, Dirk A. Zetzsche, and Robin Veidt. 2020. “Sustainability, FinTech and Financial Inclusion.” *European Business Organization Law Review* 21: 7–35.

Attridge, Samantha, and Lars Eigen. 2019. *Blended Finance in the Poorest Countries. The Need for a Better Approach*. London: Overseas Development Institute.

Banga, Josué. 2019. “The Green Bond Market: A Potential Source of Climate Finance for Developing Countries.” *Journal of Sustainable Finance & Investment* 9 (1): 17–32.

Bank of Thailand. 2020. “New Government Bond Infrastructure Launched with Blockchain Technology.’ BOT Press Release No. 59/2020. https://www.bot.or.th:443/English/PressandSpeeches/Press/2020/Pages/n5963.aspx.

Beirne, John, Nuobu Renzhi, Eric Sugandi, and Ulrich Volz. 2020. *Financial Market and Capital Flow Dynamics During the COVID-19 Pandemic*. ADBI Working Paper No. 1158. Tokyo: Asian Development Bank Institute.

Belleflamme, Paul, Nessrine Omrani, and Martin Peitz. 2015. “The Economics of Crowdfunding Platforms.” *Information Economics and Policy* 33: 11–28.

Berensmann, Kathrin, Florence Dafe, and Ulrich Volz. 2015. “Developing Local Currency Bond Markets for Long-Term Development Financing in Sub-Saharan Africa.” *Oxford Review of Economic Policy* 31 (3–4): 350–78.

Burger, John D., and Francis E. Warnock. 2006. “Local Currency Bond Markets.” *IMF Staff Papers* 53 (1): 133–46.

Burger, John D., and Francis E. Warnock. 2007. “Foreign Participation in Local Currency Bond Markets.” *Review of Financial Economics* 16 (3): 291–304.

Burger, John D., Francis E. Warnock, and Veronica Cacdac Warnock. 2012. “Emerging Local Currency Bond Markets.” *Financial Analysts Journal* 68 (4): 73–93.

Carroll, Toby, and Darryl S.L. Jarvis. 2014. “Introduction: Financialisation and Development in Asia under Late Capitalism.” *Asian Studies Review* 38 (4): 533–43.

CB Insights. 2019. *FinTech Trends to Watch*. New York, NY: CB Insights. https://www.cbinsights.com/research/report/fintech-trends-2019/.

Central Bank of Kenya. 2020a. “About M-AKIBA.” https://www.m-akiba.go.ke/index.php/about-m-akiba.

———. 2020b. “Treasury Mobile Direct.” https://www.centralbank.go.ke/tmd/.

Chishti, Susanne, and Janos Barberis. 2016. *The Fintech Book: The Financial Technology Handbook for Investors, Entrepreneurs and Visionaries.* Hoboken, NJ: John Wiley & Sons.

Clack, Christopher D., Vikram A. Bakshi, and Lee Braine. 2016. “Smart Contract Templates: Foundations, Design Landscape and Research Directions.” *arXiv preprint arXiv:1608.00771*.

Dafe, Florence, Dennis Essers, and Ulrich Volz. 2018. “Localising Sovereign Debt: The Rise of Local Currency Bond Markets in Sub-Saharan Africa.” *World Economy* 41 (12): 3317–44.

Digital Financing Taskforce (DFTF). 2020. *People’s Money: Harnessing Digitalization to Finance a Sustainable Future. Final Report of the UN Secretary General’s Task Force on Digital Financing of the Sustainable Development Goals*. New York, NY: United Nations.

Demirguc-Kunt, Asli, Leora Klapper, Dorothe Singer, Saniya Ansar, and Jake Hess. 2018. *The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution.* Washington, DC: The World Bank.

Downes, Lauren, and Chris Reed. 2020. “Distributed Ledger Technology for Governance of Sustainability Transparency in the Global Energy Value Chain.” *Global Energy Law and Sustainability* 1 (1): 55–100.

Eichengreen, Barry, Ricardo Hausmann, and Ugo Panizza. 2003. *Currency Mismatches, Debt Intolerance and Original Sin: Why They Are Not the Same and Why It Matters*. Washington, DC: National Bureau of Economic Research.

G20 Sustainable Finance Study Group (G20 SFSG). 2018. *Sustainable Finance Synthesis Report*. New York: G20 Sustainable Finance Study Group.

Galen, Doug, Nikki Brand, Lyndsey Boucherle, Rose Davis, Natalie Do, Ben El-Baz, Isadora Kimura, Kate Wharton, and Jay Lee. 2018. *Blockchain for Social Impact: Moving Beyond the Hype*. Center for Social Innovation, RippleWorks. https://www.gsb.stanford.edu/sites/gsb/files/publication-pdf/study-blockchain-impact-moving-beyond-hype_0.pdf.

Goldstein, Morris, and Philip Turner. 2004. *Controlling Currency Mismatches in Emerging Markets*. Washington, DC: Institute for International Economics.

Gonçalves, Pedro. 2019. “Indonesia Issues World’s First Blockchain Sukuk.” International Investment, 22 October. https://www.internationalinvestment.net/news/4006149/indonesia-issues-world-blockchain-sukuk.

Hartmann, Felix, Gloria Grottolo, Xiaofeng Wang, and Maria Ilaria Lunesu. 2019. “Alternative Fundraising: Success Factors for Blockchain-Based Vs. Conventional Crowdfunding.” Paper presented at the 2019 IEEE International Workshop on Blockchain Oriented Software Engineering (IWBOSE).

Herweijer, Celine, Dominic Waughray, and Sheila Warren. 2018. “Building Block(Chain)s for a Better Planet.” Paper presented at the World Economic Forum. http://www3.weforum.org/docs/WEF_Building-Blockchains.pdf.

Hofmann, Boris, Ilhyock Shim, and Hyun Song Shin. 2020. *Emerging Market Economy Exchange Rates and Local Currency Bond Markets Amid the Covid-19 Pandemic*. BIS Bulletin No. 5. Basel: Bank for International Settlements.

Howell, Sabrina T., Marina Niessner, and David Yermack. 2018*. Initial Coin Offerings: Financing Growth with Cryptocurrency Token Sales*. Washington, DC: National Bureau of Economic Research.

Hughes, Laurie, Yogesh K. Dwivedi, Santosh K. Misra, Nripendra P. Rana, Vishnupriya Raghavan, and Viswanadh Akella. 2019. “Blockchain Research, Practice and Policy: Applications, Benefits, Limitations, Emerging Research Themes and Research Agenda.” *International Journal of Information Management* 49: 114–29.

Hwang, Junyeon, Myeong-in Choi, Tacklim Lee, Seonki Jeon, Seunghwan Kim, Sounghoan Park, and Sehyun Park. 2017. “Energy Prosumer Business Model Using Blockchain System to Ensure Transparency and Safety.” *Energy Procedia* 141: 194–8.

International Monetary Fund. 2020. *Fiscal Monitor: Policies to Support People during the Covid-19 Pandemic*. Washington, DC: International Monetary Fund.

Jeucken, Marcel. 2010. *Sustainable Finance and Banking: The Financial Sector and the Future of the Planet.* London: Earthscan.

Klopfer, Alexandra. 2018. “World Bank Mandates Commonwealth Bank of Australia for World’s First Blockchain Bond.” Washington, DC: World Bank. https://www.worldbank.org/en/news/press-release/2018/08/09/world-bank-mandates-commonwealth-bank-of-australia-for-worlds-first-blockchain-bond.

Kshetri, Nir, and Jeffrey Voas. 2018. “Blockchain in Developing Countries.” *IT Professional* 20 (2): 11–4.

Lawrenz, Sebastian, Priyanka Sharma, and Andreas Rausch. 2019. “Blockchain Technology as an Approach for Data Marketplaces.” Paper presented at the Proceedings of the 2019 International Conference on Blockchain Technology.

LightCastle Partners. 2020. *Mobilizing Savings by Bangladeshi Citizens for SDG Financing*. Presentation for the UN Secretary General’s Task Force on Digital Financing of the Sustainable Development Goals. Dhaka: LightCastle Partners.

Mawdsley, Emma. 2018. “‘From Billions to Trillions’—Financing the SDGs in a World ‘Beyond Aid’.” *Dialogues in Human Geography* 8 (2): 191–5.

Mazzucato, Mariana, Gregor Semieniuk, Kelly Sims Gallagher, Anna Geddes, Ping Huang, Friedemann Polzin, Clare Shakya, Bjarne Steffen, and Hermann Tribukait. 2018. “Bridging the Gap: The Role of Innovation Policy and Market Creation.” In UNEP, *The Emissions Gap Report 2018*, 52–9. Nairobi: United Nations Environment Programme.

Muneeza, Aishath, Nur Aishah Arshad, and Asma Tajul Arifin. 2018. “The Application of Blockchain Technology in Crowdfunding: Towards Financial Inclusion Via Technology.” *International Journal of Management and Applied Research* 5 (2): 82–98.

Organisation for Economic Co-operation and Development (OECD). 2019. *Blockchain Technologies as a Digital Enabler for Sustainable Infrastructure*. Paris: Organisation of Economic Co-operation and Development.

Peters, Gareth W., and Efstathios Panayi. 2016. “Understanding Modern Banking Ledgers through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money.” In Paolo Tasca, Tomaso Aste, Loriana Pelizzon, and Nicolas Perony, eds., *Banking Beyond Banks and Money. A Guide to Banking Services in the Twenty-First Century*, 239–78. New York: Springer.

Reichelt, Heike. 2019. “World Bank Issues Second Tranche of Blockchain Bond Via Bond-i.” Washington, DC: World Bank. https://www.worldbank.org/en/news/press-release/2019/08/16/world-bank-issues-second-tranche-of-blockchain-bond-via-bond-i.

Schwienbacher, Armin, and Benjamin Larralde. 2012. “Alternative Types of Entrepreneurial Finance.” In Douglas Cumming, ed., *The Oxford Handbook of Entrepreneurial Finance*: 369–91. Oxford: Oxford University Press.

Stoutenborough, James W., and Matthew Beverlin. 2008. “Encouraging Pollution-Free Energy: The Diffusion of State Net Metering Policies.” *Social Science Quarterly* 89 (5): 1230–51.

Suri, Tavneet, Dean Karlan, and Charity Wayua. 2018. *Kenya Government Bonds as a Savings Tools*. Washington, DC: Innovations for Poverty Action. https://www.poverty-action.org/study/kenyan-government-bonds-savings-tool.

Sustainable Digital Finance Alliance (SDFA). 2018. *Digital Technologies for Mobilizing Sustainable Finance: Applications of Digital Technologies to Sustainable Finance*. Geneva: Sustainable Digital Finance Alliance.

Sustainable Digital Finance Alliance (SDFA) and HSBC. 2019. *Blockchain: Gateway for Sustainability Linked Bonds—Widening Access to Finance Block by Block*. Geneva and London: Sustainable Digital Finance Alliance and HSBC Centre of Sustainable Finance.

United Nations Conference on Trade and Development (UNCTAD). 2019. *Trade and Development Report 2019: Financing a Global Green New Deal*. Geneva: United Nations Conference on Trade and Development.

Volz, Ulrich, Peter Knaack, Johanna Nyman, Laura Ramos, and Jeanette Moling. 2020. *Inclusive Green Finance: From Concept to Practice*. Kuala Lumpur and London: Alliance for Financial Inclusion and SOAS, University of London.

Wainstein, Martin E. 2019. “Blockchains as Enablers of Participatory Smart Grids.” *Technology| Architecture+ Design* 3 (2): 131–6.

Zheng, Zibin, Shaoan Xie, Hong-Ning Dai, Xiangping Chen, and Huaimin Wang. 2018. "Blockchain Challenges and Opportunities: A Survey." *International Journal of Web and Grid Services* 14 (4): 352–75.

Zhu, Huasheng, and Zach Zhizhong Zhou. 2016. "Analysis and Outlook of Applications of Blockchain Technology to Equity Crowdfunding in China." *Financial Innovation* 2 (1): 29.