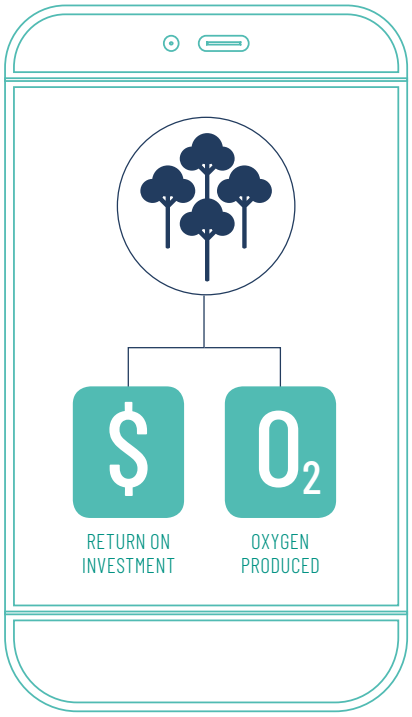
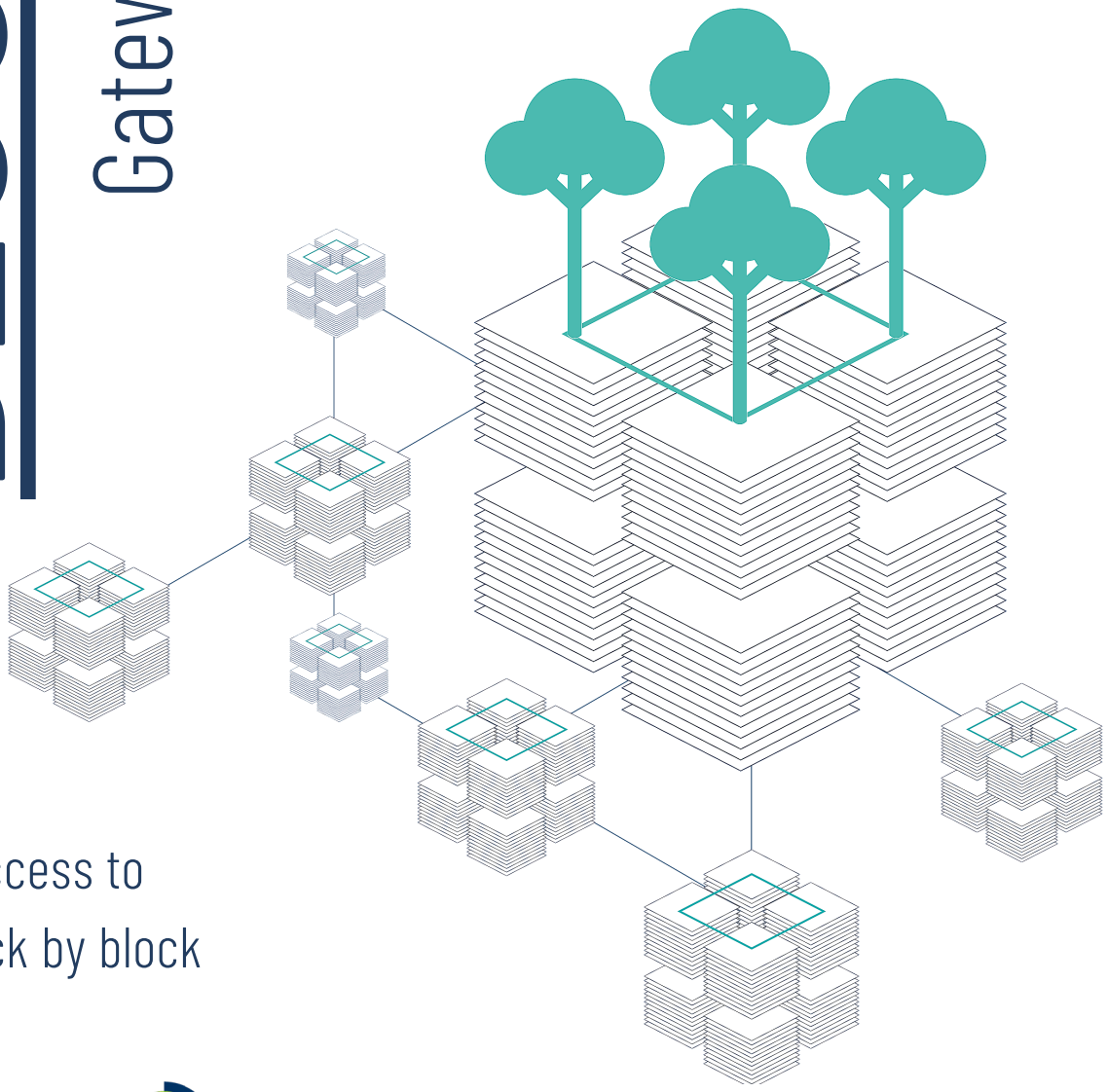
BLOCKCHAIN

Gateway for sustainability linked bonds





Widening access to finance block by block

HSBC

Sustainable Digital Finance Alliance

About this Report

This report is the result of a collaboration between the HSBC Centre of Sustainable Finance and the Sustainable Digital Finance Alliance[1] with the aim to inspire the deployment of technology to unlock more capital for the Sustainable Development Goals and the Paris agreement. The report describes how this is increasingly possible.

It particularly looks at how blockchain technology has been used in bonds, including one Green Bond, through a study of blockchain based bonds issued by banks up to Q3 2019, demonstrating efficiency and cost savings opportunities applicable to all bonds.

The report further covers opportunities especially relevant to Green Bonds, in establishing credibility for Use of Proceeds and Proof of Impact, and innovation potential for new markets, by applying blockchain and adjacent technologies already in use elsewhere, to Green Bonds. Finally, it provides key recommendations which are presented in the Executive Summary.

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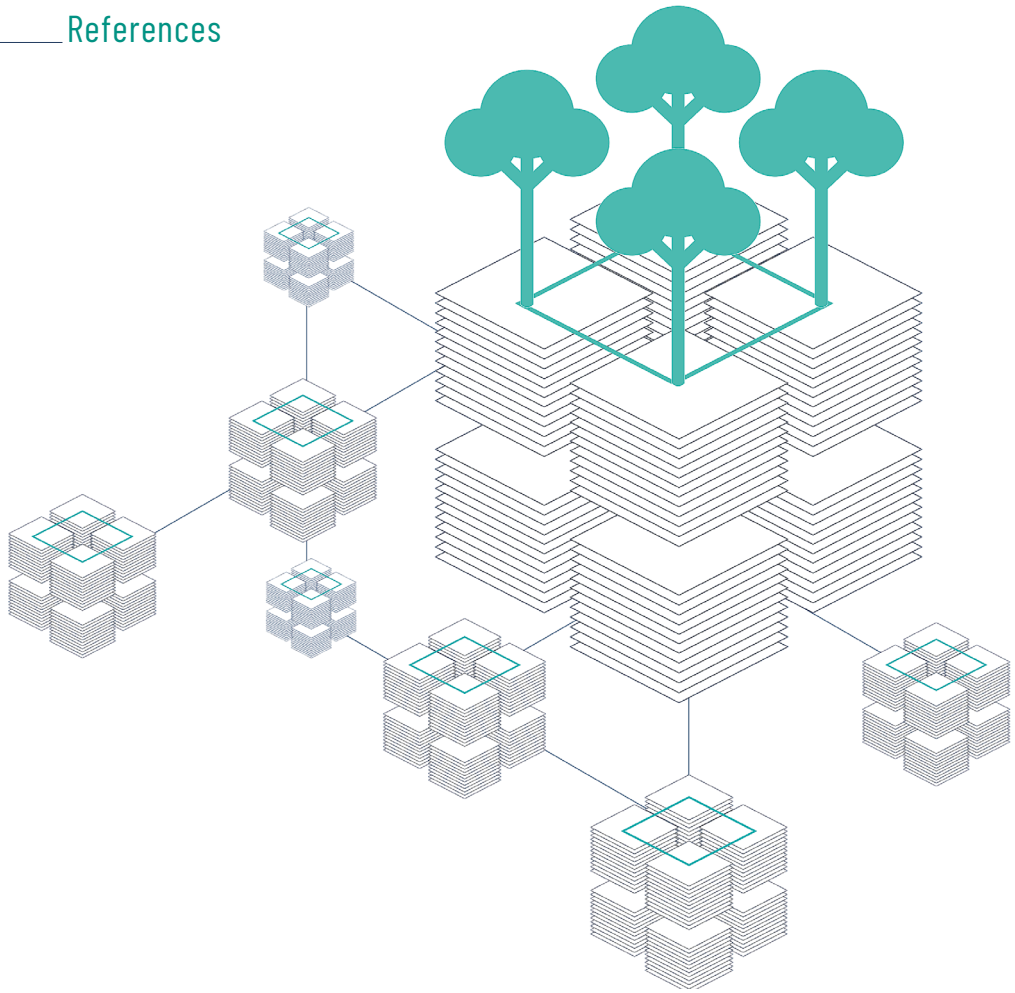


Foreword

Banks have already started to realise the benefits of using blockchain technology to issue bonds, as demonstrated by the case studies in this report. Immediate benefits for Green Bonds can be achieved by integrating IoT and AI to automatically report and to increase traceability of the performance of the green assets. For the wider bond market, blockchain presents cost savings opportunities of more than 10x, reducing the need for intermediaries and enabling smaller projects to issue bonds, which creates an opportunity for many smaller sustainable and green projects to be initiated.

While Green and Sustainable Bond issuances are USD 167.3 billion as at 2018, they still represent just 2%[2] of the total bond market share, leaving room for exponential increase in issuance to meet the annual deficit in funding for the SDGs at USD 2.5 trillion per annum[3]. Digitisation using blockchain is an avenue to accelerate scaling of the Green Bond market.

Blockchain offers the ability to digitise trust by using mathematical algorithms and cryptography to validate transactions. It can step into the bond market to take over the role of trust broker, making it easy to reduce the overall costs of bond issuance and impact the minimum coupon size. **For bonds on the blockchain there will be no difference in costs between a 10 dollar and a 10 million-dollar investment**, which will have the effect of opening up the Green Bond market to a wider investor base. Blockchain offers these advantages to all types of bonds, but recent developments at the technological frontier present even greater opportunities to Green and Impact Bonds, leading to the potential for Green Bonds to lead the transformation.

Moreover, blockchain is not developing in isolation, but is converging with both the Internet of Things (IoT) and Artificial Intelligence (AI). **Data from the real economy can be uploaded directly to the distributed ledger from sensors in a green asset and exposed to investors in real-time,** demonstrating Proof of Impact. Analytical algorithms or AI can interpret messy or difficult to interpret data before it arrives in the digital wallet of the investor. This points to a future where the current reporting burden is alleviated to make the bond market far more efficient and accurate.

Exactly how the longer-term future scenarios will play out is uncertain. What is certain, however, is that transformation of the bond market structures is increasingly possible. A blockchain powered bond market needs fewer and different participants for governance and issuance, but increases participation for issuers and investors. Current centralised market structures are unlikely to evolve rapidly because of the scale and value of current markets and the relationships of existing players.

Executive Summary

Banks have already started to realise the benefits of using blockchain technology to issue bonds, as demonstrated by the case studies in this report. Immediate benefits for Green Bonds can be achieved by integrating IoT and AI to automatically report and to increase traceability of the performance of the green assets. For the wider bond market, blockchain presents cost savings opportunities of more than 10x, reducing the need for intermediaries and enabling smaller projects to issue bonds, which creates an opportunity for many smaller sustainable and green projects to be initiated.

The original goal of this report was to map the DLT Green Bond market; however, that landscape has only unfolded to a very limited extent. The report therefore takes a broader perspective by including unlabelled DLT bonds and debt products to offer an analysis of the current state of DLT adoption in the bond market. The report finds that the opportunity presented by blockchain for DLT Green Bonds falls into the three main areas of 1) structuring, issuance and distribution 2) transfer of ownership, payment and settlement; 3) reporting on Use of Proceeds and Proof of Impact. To date, the technology has only been applied to the first two areas, and only partially in the second area, in bonds. A fully digitised Green Bond belongs to the future.

In addition, **the report highlights the countries which are the most ready for DLT Green Bond issuance**. The assessments are based on the availability of regulations which clarify the status and treatment of digital assets and identifies states which have a focus on Green Bond standards and principles. Highlighted countries include Luxemburg, Germany, Switzerland, Singapore, Seychelles, Mauritius and the Philippines.

Efficiency gains are calculated both by companies studied and the analysis conducted for this report to more than 10X the non DLT bond process with the largest efficiency gains (as money saved) in Green Bond reporting, brokerage and sales as well as structuring, price setting and risk rating. The report concludes that in addition to efficiency gains, digitising Green Bonds with DLT opens up for transformational follow-on innovations. Two innovations with high impact potential are highlighted: the fragmentation of green asset ownership; and the aggregation of many smaller assets into a bond. These findings highlight the opportunity to unlock savings into green finance and enable more people to become green asset owners.

How far and how fast the bond market will step into a blockchain powered reality will also depend on contemporary regulators and policy makers. However, as this report demonstrates, banks and other ecosystem players are already finding opportunities to move small parts of the market, and this trend is likely to accelerate, with Green Bonds presenting a more pressing case than traditional bonds and therefore a key opportunity to lead the transformation. Overcoming the barriers will allow for a shift away from a slow and cumbersome, expensive process with the weight of stakeholders on the issuance side, to an accessible, democratised process with more agility and accessibility for new types of investors and projects.

Recommendations

The following five recommendations are made based on the series of interviews and literature reviews which has generated the data for this report:

RECOMMENDATION 1)

Pilot moving all steps of Green Bond issuance onto a DLT platform: Financial service institutions to pilot digitising all three steps of a Green Bond issuance process, including Stablecoins for automatic settlements and for pay-outs to investors and offering regulators a node for full transparency, oversight, and learning. It is further recommended to conduct a fully digitised Green Bond pilot in one of the jurisdictions identified as having a regulatory readiness for DLT Green Bonds. The pilot can inform the development of an open source standard for blockchain based Green Bonds similar to ERC-20, the most popular Ethereum token protocol for digital assets.

RECOMMENDATION 2)

Offer Green Bonds as Security Tokens over public exchanges: Banks and issuers can exploit DLT to offer fractionalised instruments in primary or secondary trading direct to small investors over public blockchain exchanges, or via stock exchanges supporting Security Token trading, thus engaging a wider investor population.

RECOMMENDATION 3)

Shift from manual reporting to Data Tokens: Apply automated reporting from assets to harvest recognised metrics, codified as data tokens that communicate in real-time to investors and build a shared asset history on the ledger, aggregating for projects but accessible to multiple stakeholders. Learning from and partnering with existing Proof of Impact tokenisation and real-time reporting, this will be one of the most transformational steps for the Green Bond market.

RECOMMENDATION 4)

Bonds as a Service: "Do it Yourself" bond platforms are emerging which allow issuers to create their own DLT Green Bonds at low cost and offer them in some markets via Security Tokens. This will enable smaller entities such as medium-sized businesses or communities to issue Green Bonds directly without the need for costly full-service offerings by banks. Regulators and policy makers can pave the way for this avenue to scale Green Bonds by unlocking savings. These new forms of community Green Bond offerings could be just around the corner if regulators enable this market.

RECOMMENDATION 5)

Establish regulatory clarity and consensus on crypto assets: Governments can look to frontrunner countries such as Luxembourg and Switzerland which have issued crypto asset regulatory frameworks to enable issuance of Green Bonds as Securitised Tokens to become regulated instruments. Regulators can support these avenues to unlocking new types of Green Bonds by ensuring Security Token regulations are clear and offer tax incentives for citizens to put their savings into these new types of micro DLT Green Bonds. Further, banks can also offer advice and potentially insurance products to this new market.

The body of this report goes into more detail starting with the Current state of the blockchain bond market, and in turn is supported by analysis and explanations of the technology landscape in the Annexes at the end of the report.

PART 1:
CURRENT STATE OF THE BLOCKCHAIN BOND MARKET

"The most impactful benefits that will allow scaling are yet to be realised"

Current state of the blockchain bond market

Since early 2018, several financial institutions have issued bonds and other debt products using blockchain technology, primarily for structuring, issuance and asset transfer. While by Q3 2019 there was limited activity on labelled "Green" blockchain bonds, some have also been aligned to the sustainable development goals. Automated impact reporting, automated coupon payments using digital assets and full distribution by opening up investment opportunity using automated "Know Your Customer" (KYC) are not yet part of the bond landscape. The most impactful benefits that will allow scaling are yet to be realised.

This section presents key innovations in blockchain bonds by financial institutions and related developments in blockchain applications to debt and financial products. It discusses opportunities that have been exploited alongside those that are yet to be fully realised, and presents the landscape for how blockchain based digital assets in banking are evolving to support this market.

It explores the different approaches taken by the banks to blockchain bonds, and the countries most likely to advance blockchain Green Bonds in the future. Fuller technical explanations and discussion can be found in the Annexes (Page 33).

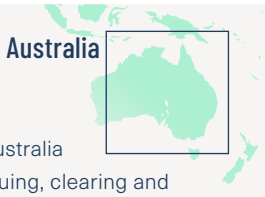
The current landscape of blockchain powered Green Bonds consists only of one bond issued by BBVA[4]. Therefore, this landscaping includes non-labelled bonds powered by the blockchain to understand how far the bond market has stepped into a blockchain based approach, providing foundational structures for Green Bonds.

How blockchain is currently applied to bonds

Green bond and labelled bond applications of blockchain fall into three main areas:

1. **Structuring, issuance and distribution**
2. **Transfer of ownership, payment and settlement**
3. **Benchmarking and reporting**

The first two areas apply to all bonds and to date, the technology has only been applied to these two, and only partially in the second area. **The blockchain based bond market is most mature in using the technology for structuring, registration, sales and distribution**. In most cases the sale has been limited to pre-authorized investors where Know Your Customer has happened off-chain. Investors have been able to place orders via a digital interface using an authentication key. The platforms developed by the banks have allowed for automatic book building in real-time.



World's first publicly offered Blockchain Bond

The bond-i, issued by the World Bank in partnership with Commonwealth Bank of Australia (CBA's) Digital Innovation Lab5, used blockchain technology to replace registry, issuing, clearing and custodian processes with smart contract automation on a private version of the Ethereum blockchain.

Investors and participants in the bond process were authenticated by the World Bank and CBA before being given access to the system, allowing for a Proof of Authority AuRa (Authority Round) protocol. The benefits included direct and secure holding of assets without custodians, fast processing for investors, no need for reconciliation of data across bond market actors as all have access to the same ledger, full visibility of transactions for the World Bank and the potential for real-time reporting for regulators, who could have had a node on the blockchain with observer privileges.

The bond-i was subsequently offered on secondary markets6 using the same blockchain platform. CBA will form part of the consortium of banks now working on expanding their issuance to other bonds. In August 2019 the World Bank reopened the original bond to one existing and two new investors7, increasing the issue size to AUD 160m. Positive outcomes included a reduction in the number of intermediaries and a more immediate communication between investors and issuer.

World's First Blockchain GREEN Bond

In February 2019 BBVA issued the world's first Green Bond using blockchain, for EUR 35 million, on behalf of MAPFRE[8] using a fully automated blockchain platform that allows the client to structure the instrument directly. Like the World Bank, they used the technology primarily to "simplify the processes and streamline the negotiation time frames" with investors.

BBVA used a version of Hyperledger Fabric permissioned blockchain, accessible only to authorised counterparties such as investors, for issuance of the first Green Bond over blockchain, with the record of the transaction written to the public Ethereum Testnet for full visibility to any observer, as with previous debt products. As well as offering customers access to their platform, BBVA also gave customers the option of hosting a node of the blockchain, which about half of them accepted.

In issuing this Green Bond, MAPFRE and BBVA still underwent the traditional third party validation process for Green Bonds, by DNV GL[9].

Where blockchain is only partially or not applied

All of the bonds included in this report used **structured tokens** for transfer of ownership of the bonds. However, none of the bonds issued by financial service institutions used blockchain for payments and settlement, keeping payments off-chain. In the case of the World Bank bond-i, the reasons for not using blockchain technology to automate settlement and payments were both cultural and regulatory. The partner bank CBA has an internal **cash on ledger coin** or **Stablecoin** (Yellow Coin) but, as with all bank-issued coin up to Q3 2019, this Coin inherits the risk rating of the bank rather than that of the issuer or a central-bank issued currency, which in this case is greater than that of the issuer, the World Bank.

Commerzbank, however, has been using cash on ledger for settlement of other debt instruments, demonstrating not only that it's possible to use Cash on Ledger for settlement, but also that it reduces cost and risk of settlement. For blockchain based bonds to fully digitise payments longer term, there is a need for regulatory clarity of blockchain based digital assets, and/or a Central Bank Digital Currency, although Stablecoin projects such as Fnality (described below) are likely to prove useful in the short term.

Stablecoin as a settlement instrument

Stablecoin is a type of blockchain based digital asset that is pegged to a national currency. Many commercial banks have been experimenting with Stablecoins as a means of internal value transfer and settlement, with some offering them as instruments for use by customers, such as JP Morgan's JPMCoin or Commerzbank's settlement instrument. Bank Stablecoin is usually called **"cash on ledger"** rather than a coin, partly to avoid the perception of risk associated with crypto assets. Regulatory challenges[10] that apply to non-bank issued Stablecoin are largely overcome by banks' regulatory framework.

The **Stablecoin model** is favoured by banks for securities settlement because it maintains the fiat value of the transaction, however, unlike fiat currency, which is guaranteed by a Central Bank, **Cash on Ledger** carries the risk of the issuing bank.

The Fnality initiative supported by 14 banks moves beyond this risk, by collateralising the currency with cash held at Central Banks, bringing the risk closer to that of Central Banks, and will be useful for settlement between institutions as well as for customers.

Many central banks are experimenting with a Stablecoin as a **Central Bank Digital Currency (CBDC)**, to reduce cost and increase efficiency in Real Time Gross Settlements (RTGS), which will extend longer term into securities settlements. China has been the first to authorise a national CBDC, with both a commercial layer for settlements and a retail layer managed by commercial banks.

De-risking Stablecoin for settlement

Fnality[11] is an innovation in Bank-issued Stablecoin targeting Wholesale interbank transactions backed by UBS, Barclays, Banco Santander, BNY Mellon, CIBC, Commerzbank, Credit Suisse, ING, KBC Group, Lloyds Banking Group, MUFG Bank, Nasdaq, Sumitomo Mitsui Banking Corporation, and State Street. Launching in 2020, it will issue Stablecoin backed by cash reserves held at Central Banks in five currencies - USD, CAD, GBP, JPY and EUR.

Legal settlement happens within the blockchain, as opposed to within the bank, making it equivalent to cash rather than bank-issued currency, while the escrow held with central banks reduces the risk from that of any one of the issuing bank, to somewhere between Commercial and Central Bank risk. It's likely that Fnality will be exchangeable with other Bank-issued Stablecoins and open the doors for an interoperable commercial bank settlement network suitable for securities settlements.

Other experiments with Blockchain Bonds

Société Générale[13] ran a pilot issuance of the **first covered bond over blockchain**, again building on previous lending experience, in early 2018. They issued their product directly onto the public **Ethereum blockchain**, as **Security Tokens**, with the potential to make them widely available to many investors, although in the pilot, Société Générale was the sole investor, avoiding the need to address KYC and marketing challenges.

BMO[14] have run some experimental **shadow bond processes** but are **waiting for regulations** to develop before proceeding.

Other organisations have announced they are planning to issue blockchain based bonds or are indicating projects in the pipeline: Nomura and NRI, a technology provider, have announced a corporate bond platform that will be operational from 2020[15]. SIX Digital Exchange[16] in Switzerland will be the first market infrastructure in the world to offer a fully integrated end to end trading, settlement and custody service for digital assets, while Mauritius and the Seychelles exchanges have also announced they will be trading digital assets. Austrian government bonds have been notarised using blockchain technology to strengthen validation in bond auctions[17].

Argento, a securitization firm, and London Block Exchange (LBX) announced a **Bitcoin-denominated bond**[18] in July 2019, which is regulated under the UK's Financial Conduct Authority (FCA).

While such products are attractive to some customers such as governments in developing economies, it's unlikely that floating cryptocurrencies such as Bitcoin will be attractive to traditional investors until the time when a much wider range of alternative currencies has evolved and regulatory uncertainty surrounding them has been settled.

By Q3 2019, bond market participants born as **software companies** are the exception compared to the vast majority of bonds. A platform such as Bitbond[19] conduct transfer of ownership, payment and settlement on-chain and this is a fully regulated manner.

Bitbond was the first to conduct a fully regulated **Security Token Offering** (STO) for their bond in the EU, with a BaFin licence[20] for their BB1 Security Token. Bibond used the **Stellar blockchain** and BB1 tokens are automatically transferred into an investor's Bitbond **wallet** when placing an investment. **Smart contracts** manage coupon payments using Stellar Lumens, Stellar's cryptocurrency. Investors can transfer ownership between each other, by transferring between **wallets**[21].

Many Blockchain exchanges, which originally supported issuance of ICOs (Initial Coin Offerings), the widely discredited and unregulated tokenisation of assets, are now starting to offer STOs, mostly for Equity, but have the potential to become actors in the Securitised bond market.

An analysis of key Debt Products issued by banks using blockchain and other relevant projects is in Annex 6.

The People's Bank of China

The People's Bank of China (PBOC) has announced that it has authorised a Central Bank Digital Currency (CBDC)[12] based on a two-layer system, with one being for commercial use and the other for retail. It's planned that it will be escrowed by a store of national fiat currency (RMB) 1:1 to avoid impacting the money supply.

There are open questions around the use of blockchain for the retail layer, however PBOC have announced that it will support anonymity and encryption features as well as peer-to-peer payments without going through a bank, implying blockchain will be used. PBOC has been working on this currency for five years, and it was assumed in the industry y that they would, like other Central Banks, start with a RTGS (Real Time Gross Settlement) system before progressing to the more challenging retail market, with higher transaction volumes.

However the announcement of Facebook's Libra project has accelerated the PBOC into presenting a viable alternative, to mitigate the risk of capital flights weakening the RMB.

State of Current Ledger Design Choices

Most of the banks issuing bonds are doing so on **private blockchains**, although the Société Générale offering was directly onto the Ethereum public blockchain, as Security Tokens, albeit in a closed experiment, which enabled Société Générale to build its Security Token on the widely used asset token ERC-20[22]. All the other projects included in the research have either built on or defined new standards to support the complexity of their product; in addition to the adoption of new protocols, different approaches to the question of public/private and levels of permission have been taken:

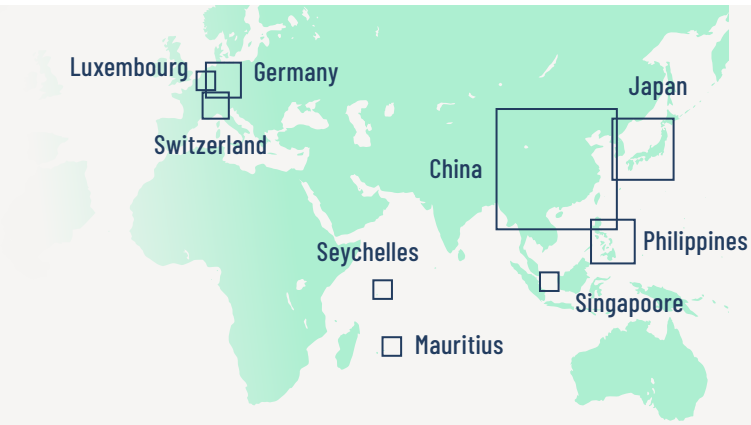
State of Current Ledger Design Choices

- **World Bank/CBA** built a private, permissioned version of **Ethereum** with a very small number of nodes shared only by the issuers; a node was also offered to regulators. Access to the platform was given to authenticated and vetted investors.
- **Commerzbank**, who were one of the original R3 consortium developing the Corda ledger platform, developed an internal private, **permissioned version of Corda**, with access for authorised investors.
- **BBVA** used an internal blockchain developed on **Hyperledger Fabric**, which is a private, permissioned blockchain, but registered the transaction on the **public Ethereum testnet** after issuance. This enabled them to ensure only fully validated investors had access to the platform for investing in the bond, but full transparency that the transactions had taken place.
- **Provenance.io** has developed a purpose-built version of what was originally **Hyperledger Fabric** (and therefore a **private, permissioned network**) but is no longer recognisable as such, specifically for bank debt security trading.
- **Société Générale** have issued a covered bond as a **Security Token** directly on the **public Ethereum blockchain**, in theory allowing any investor to access the bond. Uniquely among the bank bonds studied for this report, their pilot demonstrates the opportunity to democratise sale of bonds in very small units.

State of Regulatory Readiness for Blockchain Green Bonds

This section presents countries identified as the most prepared for blockchain based Green Bonds, as a support for those considering issuing them. As of Q3 2019, just over **USD 1 billion has been raised via Security Token Offerings**, a number dwarfed by global bond markets at 100 billion[23]. The market has been driven by the UK, USA, Switzerland, Germany and Estonia. In this analysis, we have selected markets that have a maturity of research and/or defined legal frameworks for Security Tokens, and those with greatest Green investment potential.

State of Regulatory Readiness for Blockchain Green Bonds



European regulators follow ECB guidance, but vary in specifics on classification of and regulation of crypto digital assets. **Luxembourg** was one of the first countries to issue a legal framework for Security Tokens[24], and has been recognised as a Green Bond pioneer as its Green Stock Exchange, giving access to half the world's listed Green Bonds[25].

BaFin, the German regulator, has classified Security Tokens as Digital Asset[26] and was one of the first European countries to authorise an STO (BitBond's[27]). German regulations regarding paper for bonds are being revised to digital registration. Having been the source of half of European green debt in 2019, **Germany** is planning to issue a Green government bond[28].

Switzerland has evolved as one of the more crypto friendly countries, and has regulated Security Tokens under FINMA[29], as asset tokens. It's also the home to SIX Exchange, one of the first to declare it will trade STOs, and a mature secondary Green Bonds market[30], making Switzerland a leading contender in Europe for Green Blockchain Bonds.

Like the **Seychelles**, th island nation driving Blue bonds[31], **Mauritius** has declare SecurityTokens securities[32] and further announced they will be traded on its stock exchange, with a parallel Green Bond drive[33].

In **Asia**, **China** has dominated Green Bond markets, and is close to issuing a government backed digital currency, which will enable a faster digitisation of the Green Bond market. However, restrictions on digital assets in China may act as a barrier to the growth of blockchain based instruments.

Japan has developed a robust framework for Security Tokens[34] and issecond only to China in Green and Climate Bond issuance in the region, with a strong focus on green buildings[35].

Singapore has a clearly defined legal framework for Security Tokens[36], which are treated like any other security, and an openly welcoming approach to technology innovations supporting the banking sector. It's also actively promoting sustainable investment[37].

The **Philippines** has released a **framework for Security Tokens**[38] and recognises digital assets, with a push for Green investments motivated by climate related natural disasters[39]. The Philippines presents the opportunity to trial a blockchain Green Bond, with positive conditions for issuance, in a country in need of greater transparency to boost markets[40], with an urgent Green agenda.

A developing blockchain bond landscape

The number of jurisdictions with regulatory readiness, and financial service institutions progressing experiments with blockchain based bond issuance, points to readiness to take the next step into fully digitising all three steps of the bond process. A learning blockchain based Green Bond, where regulators get a node and bond market participants trial automated reporting and Stablecoin payments, will be a further step forward. As the landscape shows, some countries are well prepared to engage with the next step.

PART 2: EFFICIENCY

"The calculated price difference estimates for standard issuances versus a full blockchain automated issuance for a typical Green Bond with a value of 100 million USD and 20-year maturity"

Efficiency

Using blockchain has enabled banks to reduce time and cost of issuance, while creating a more immediate relationship between issuer and investor. These efficiency gains, which apply to any type of bond, provide the groundwork for both application to Green Bonds, and for additional gains specific to Green Bonds explored in later chapters. Annexe 1 describes the Blockchain Bond Toolkit, for further details of how the technology can be applied.

The average US corporate bond carries origination expenses of ~3-6% of funds raised[5]. Blockchain offers efficiency opportunities in bond issuance and distribution in a number of ways, as outlined below.

1) **Reduction in the number of actors:** DLT can replace many of the actors in today's bond process. Using smart contracts for bond issuance and distribution brings greater transparency and reduces risk for issuers, investors and underwriters, meaning several parties, such as brokers and listing agents, can be removed from the process. There is potential to significantly reduce the role of banks in market making and managing investor relationships while they will retain key responsibilities as advisor and trusted authority for trust processes such as KYC.

2) **Immediacy of distribution:** Bonds are complex instruments with many variables such as term, coupon rate, risk rating and other conditions. Exchanges are set up for simpler instruments, so more complex bonds are instead mostly sold directly to investors through brokers or Over the Counter on secondary markets, as exchange listing requires a paper review process. Investor search and matching (whitelisting) presents considerable effort compared to distributing equity over public exchanges. Smart contracts can handle complex rules for competitive bidding, creating opportunity for fully automated issuance and distribution.

3) **Efficiency in reduced reconciliation**: Since they are written to the blockchain, smart contracts remove the need for human oversight. Cryptographic signatures guarantee they are tamper-proof, removing the need for anti-fraud or error checks and 4-eye processes.

4) **Efficiency in settlement:** DLT based smart contracts can perform **two-way instant transfer** of value and assets without the need for a separate settlement process, by transferring a digital asset in exchange for a **token** representing the security. **Stablecoins** in a bond can move value between investor and issuer with maturity and settlement automated to **remove intermediaries** and **manual processes**. Stablecoin can facilitate distribution of dividends through smart contracts. Reasons for using Stablecoin for settlement include:

   a) **Banks are well placed to issue Stablecoins** (digital currencies pegged to a fiat currency) under their existing fractional reserve licencing arrangements;

   b) Introducing a Stablecoin for payments allows execution of contracts to trigger payment and instant settlement, reducing settlement risk by over 99%[42], eliminating counterparty risk and elapsed time, and significantly reducing costs; and

   c) Efficiency gains emerge from a 2-3 days settlement to that process being instant.

A comparative analysis of Green Bond costs with and without blockchain

Bond issuance includes hard costs associated with resourcing the processes and paying third parties, and opportunity cost associated with the long timeframe before a bond is available to the market. Green bonds also need internal review, third party validation and Proof of Impact reporting. Costs are hidden in most organisations[43], being regarded as "part of the process", so the study identified different processes as pain points, while others are accepted as business as usual[44]. The methodology assessed the typical cost of issuance in the market at Q3 2019, based on:

- Literature review of typical fees, which includes % of bond value (e.g. for brokerage) and fixed fees (e.g. legal), averaged over different jurisdictions.
- Estimate of time spent on different processes based on literature review and interviews, together with typical costs of resources.
- Opportunity cost of settlement.
- Currently used practices in non-blockchain and blockchain bonds, together with current practices for Proof of Impact.

Cost estimates in the table below include fees charged by institutions, platforms and professional services as well as "hidden" costs absorbed into BAU for institutions. While not all of the fees can be removed - for example, legal and accounting fees will be incurred, albeit to a lesser extent, and some costs will increase, the net impact is a dramatic reduction in costs. Green Bond specific challenges have been derived from UNEP[45] and Green Bond Principles[6].

The table below provides the calculated price difference estimates for standard issuances versus a full blockchain automated issuance for a typical Green Bond with a value of 100 million USD and 20-year maturity.

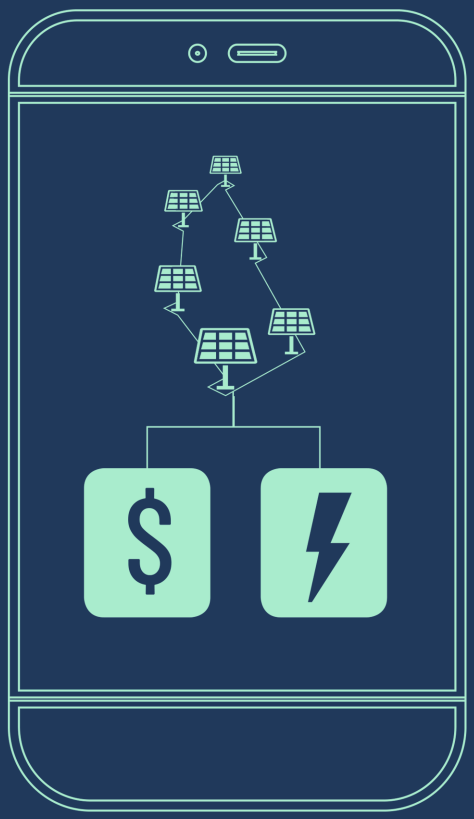
Standard vs Blockchain Cost Estimates Comparison Table

GREEN BOND PROCESS (USD)	STANDARD PROCESS	WITH FULL BLOCKCHAIN AUTOMATION
Structuring, price setting, risk rating	1,000,000	20,000
Legal review	100,000	40,000
Investor whitelisting and matchmaking	500,000	n/a
Internal review and green classification	50,000	20,000
Third party validation and green benchmarking	50,000	5,000
Registration and listing	15,000	n/a (if sold on blockchain exchange)
Brokerage and sales	1,500,000	40,000
Payment and settlement	Opportunity cost: 84,000	0
Custodianship	350,000	2,000 (blockchain dependent)
Data gathering (full lifecycle)	1,200,000	350,000 (includes IoT devices)
Data aggregation (full lifecycle)	400,000	115,000
Reporting (full lifecycle)	1,200,000	100,000
Total	**6,449,000**	**692,000**

These cost savings assume the bond is issued in isolation in today's market. Mass automation using DLT will open the opportunity for more investor side automation and market opportunity for issuance of more, lower value bonds, further reducing the unit cost.

Cost savings and efficiency gains using blockchain can be significant. For Green Bonds, with their need for reporting, the savings can be even greater. However, one of the key challenges facing Green Bonds is building credibility in markets where trust is low. Here, blockchain presents even greater potential to increase trust and therefore scope for new markets.

PART 3:
CREDIBILITY



"The green data in these wallets can be owned by the project and any investor in need of that data can simply pull it out of the digital wallet"

Credibility

While efficiency will drive down the costs, and present opportunities for smaller, more widely distributed bonds, Green Bonds will benefit even more from the market opportunities presented by enhanced credibility. This chapter explores how blockchain and adjacent technologies are being used to validate data proof, and how this can be applied to Green Bonds, together with opportunities presented to the reporting process.

Credibility will be improved by three main properties of a blockchain powered bond.

- Firstly, by shifting the validation of Proof of Impact from a third-party review to traceable, tokenised data based on automated sensors at the source
- Secondly, by using Stablecoin for capital flows with full transparency of the Use of Proceeds
- Thirdly, by giving every investor direct visibility of how the Green Bond develops and performs in real time unfolding on their screen.

IoT technology, combined with DLT, is already being used by green assets and projects automatically reporting on Use of Proceeds via data tokens[47] and rewarding participants for sustainable behaviours. This can be done through the deployment of a sensor such as a RFID tag, visual monitoring, or a blockchain enabled chip embedded in the green asset which sends data a 'data token', programmed to conduct payouts or other tasks when it receives specific data sets from the asset.

This approach has not yet been applied to the Green Bond market, however it presents a real opportunity to integrate into bond products, and ultimately build green reputation wallets for all green projects and assets eligible for Green Bond issuance.

Automated harvesting of green data

Tokenised Proof of Impact is already being used for sustainability projects such as UNDP's CedarCoin initiative[48], which is reforesting depleted forests in Lebanon through diaspora donations. Proof of Impact tokens give donors immediate feedback with GPS located pictures of trees when they are planted, while Clean Air LifeTokens are generated as rewards for those looking after the trees, which in turn can be exchanged for DAI Stablecoins and local goods and services.

This immediate Proof of Impact and tokenisation confers value on conservation behaviour directly related to the oxygen produced by the tree, and its contribution to improving the environment. The value-add is measured and monetised while it's alive, in real time, rather than waiting to cash out value once it's harvested, or waiting for lengthy data collection and reporting through timesheets. Similarly, the Global Mangrove Trust[49] combines AI monitoring of forest density with TreeCoin rewards that can be exchanged for goods, while FishCoin[50] can be exchanged for mobile minutes as it provides traceability.

From Manual to Automated reporting

However, data do not always come in well-structured formats; automated data gathering can result in huge datasets, so advanced analytics are needed to make sense of the data and categorise it. Measurement can be direct, for example units of carbon, or derived, such as economic or climate impact. For example, output from a monitoring device sensing NO_2 needs automated analysis, to eliminate noise and compare with results from other sensors. That data can then be presented in raw form as a measure of air quality, or combined with CO_2 and other measures to create a climate impact index. Climate indicators from multiple monitoring points over time provide raw data for trend analysis, giving a clear and simple view of the impact of the project.

The lack of common standards commonly cited as a reason for inconsistent, manual processes can be overcome by moving to a pull reporting system where data is harvested from projects or platforms. Pull reporting allows different customers of data to harvest what's important to them, from a variety of sources, usually through APIs or with AI queries based on a reputation system.

A set of data, held in a "wallet" or "reputation" associated with the project or assets in the project such as trees, solar panels or buildings, would provide the opportunity to standardise data management for projects while allowing for complex reporting by multiple stakeholders without the need for arduous paper exercises. Such a wallet can be queried by multiple measurement systems without the need to present different data sets to each, or the need for all the wallets to standardise. The green data in these wallets can be owned by the project and any investor in need of that data can simply pull it out of the digital wallet. In addition, the risk of duplication and double counting such as with carbon credits, can be reduced with the use of smart contracts and other protocols[51].

Metrics ready for automated reporting

Data gathering is not straightforward and even with the proliferation of IoT devices, or perhaps because of this, defining the right data to collect, and identifying how to collect it, is extremely challenging, but defining the right metrics to use is critical to incentivising the needed behaviours. In the current dominant sector of climate aligned bonds in developed markets being transport, energy and water according to the Green Bond State of the market in 2018. **These three sectors are already using automated data harvesting via IoT devices, which can be applied to the reporting on Green Bonds.** For developing markets, the top three sectors are energy, land and transport[52], with data available that can be harvested.

Steps towards Credibility

As the examples cited in this section demonstrate, automated data gathering using **IoT devices and blockchain are already being used to demonstrate Proof of Impact in donor projects and in financial value chains.** These technologies are maturing rapidly and are now at the point where they can be applied to large scale financial projects. The acceptance of Stablecoin beyond closed banking ecosystems and digital assets enthusiasts has yet to grow to levels where Stablecoin will be commonly accepted by investors as a settlement instrument, however markets are evolving and awareness has been increased by the announcement of Libra and JPM Coin, with Fnality likely to emerge as a widely accepted settlement instrument in the near future, leading to wider future opportunities.

PART 4:
INNOVATING THE GREEN BOND MARKET

"This points to a future where being a green asset owner is accessible (and transparent) to everyone and where savings can find purposeful deployment opportunities."

Innovating the Green Bond market

The application of DLT in existing projects and opportunities for efficiency and traceability described in previous chapters exploits features of blockchain based automation. Based on other applications of blockchain already in use across other industries, further benefits to the bond lifecycle can be explored in addition to those described above, which are yet to be implemented. Combined with emerging distribution opportunities these innovations can open new markets at both ends of the bond investment pipeline.

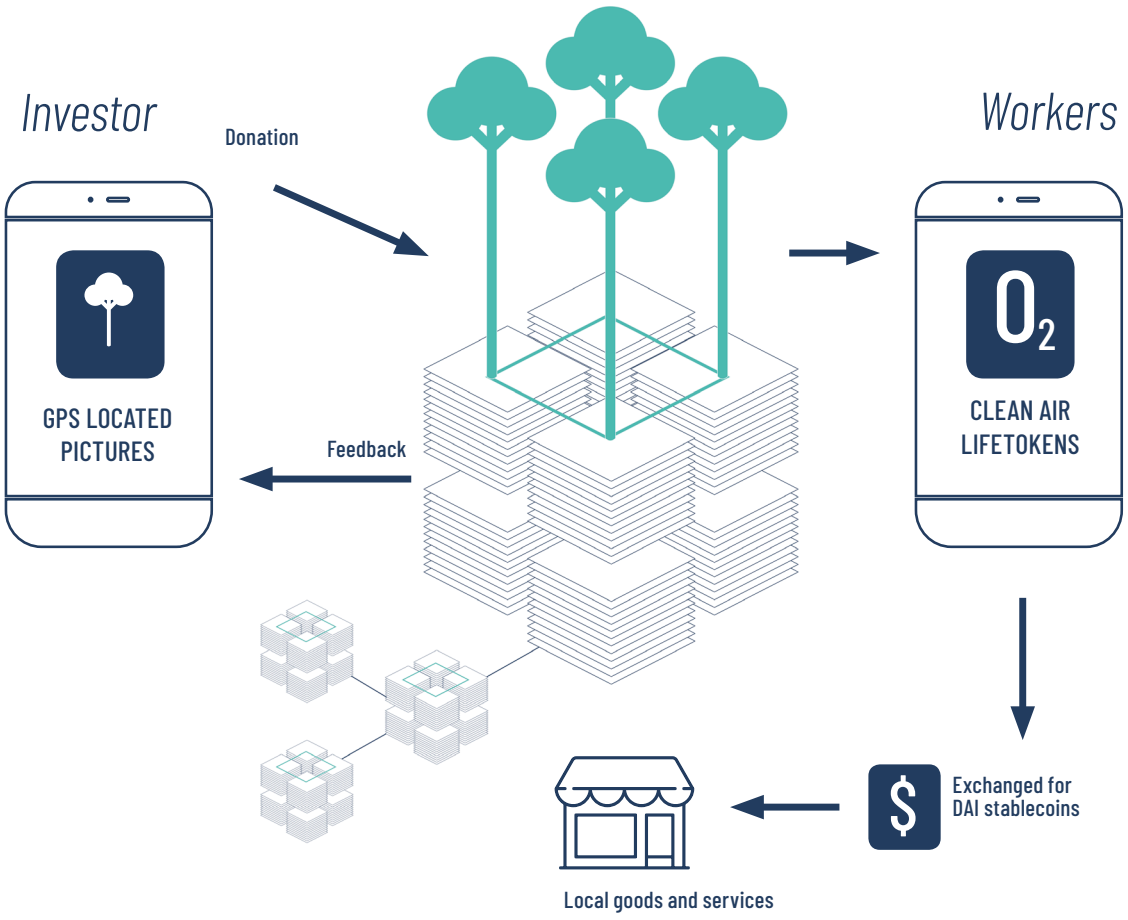
Efficiency, transparency and greater confidence all add up to a more efficient market. The transparency and ease of ownership is likely to increase investment in Green Bonds, especially as greater efficiencies lead to more attractive coupons. Beyond making today's Green Bond market more attractive to investors and issuers, the technology also presents the opportunity to create new markets at both ends of the investment pipeline.

Innovation 1)

"Bonds as a Service" - increasing accessibility to issuance through automation

Bond automation through DLT presents the opportunity to encode standardised bond issuance, allowing for bond structuring as a standard software toolkit. As service providers such as **blockchainbond.io**[53] start providing services to international issuers, Bonds as a Service is likely to provide more, smaller issuers the opportunity to raise capital through bonds.

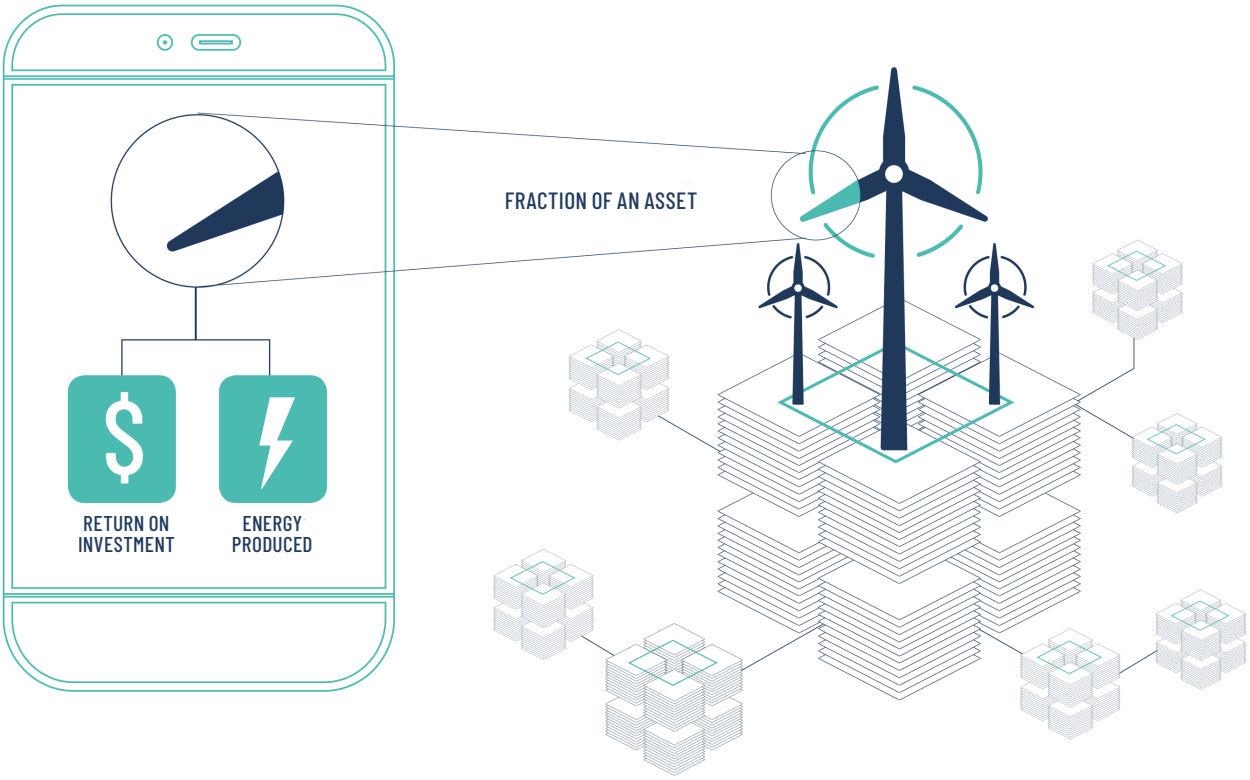
When investors embrace a similar approach, automating business rules on the buy side, the combined automation will create an opportunity for large numbers of **lower value bonds** to be traded automatically, catapulting the slow-moving world of bonds closer to a straight-through, blockchain-based rules automation process.



Innovation 2)
Fractional asset ownership

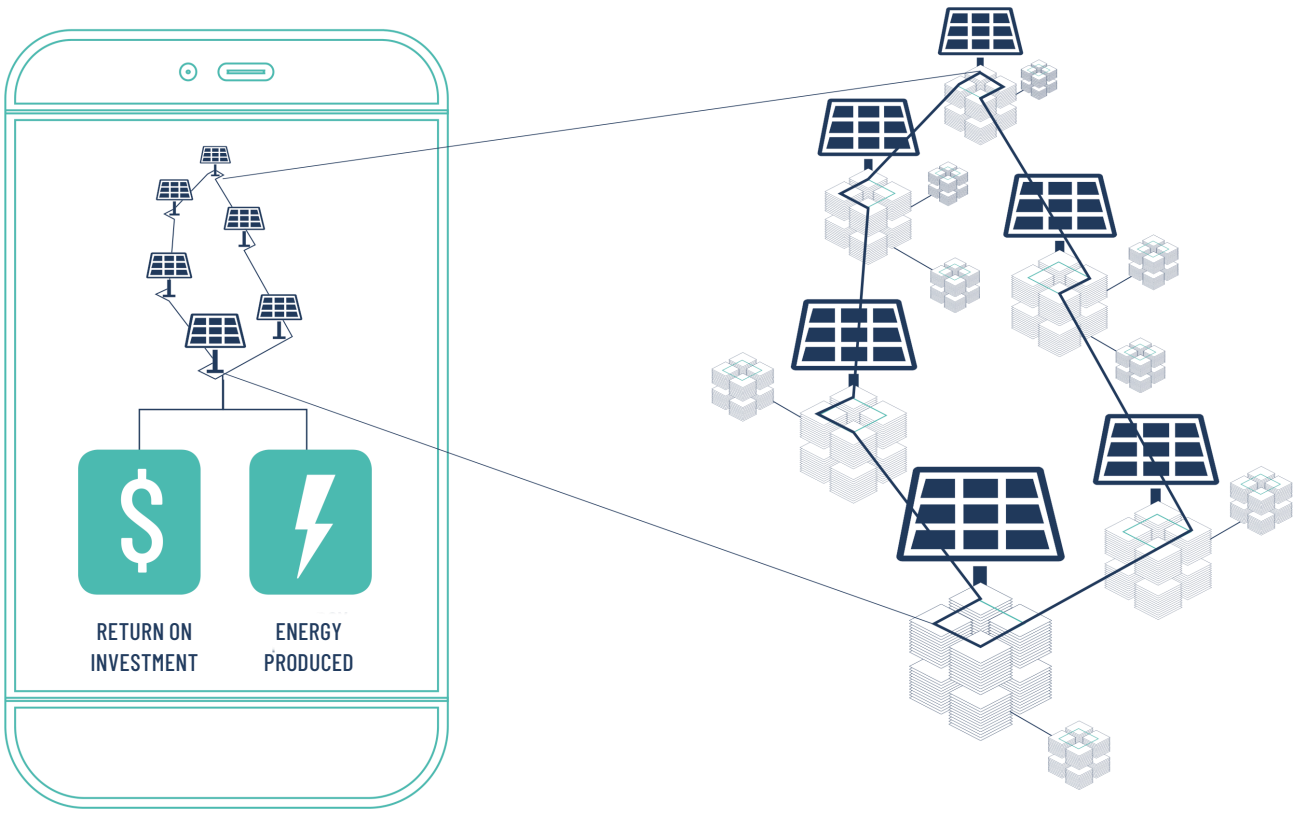
The greatest innovation opportunity for asset ownership is in **fractionalising the asset** - bond or other - into many small units, which can be **directly owned** by the investor rather than through a portfolio product such as an ETF. Combined with automated reporting, small investors can also monitor the real time progress of their investments. This points to a future where being a green asset owner is accessible (and transparent) to everyone and where savings can find purposeful deployment opportunities. For this follow-on innovation opportunity to be fully unlocked investor protection and insurance products needs to arrive.

It is essential to progress rapidly to practical projects which exploit DLT and adjacent technologies, to increase funding for projects combating climate change and supporting community infrastructure in frontier countries. Despite multiple barriers and the evolving nature of the technology, the components needed to move to the next stage are in place. Financial institutions are well positioned to drive this action within their existing sustainable investment portfolios and must take responsibility for doing so.



Innovation 3)
Aggregation of investable assets

As well as major infrastructure and large projects such as forests, investment is needed to support growth in minor infrastructure like community irrigation systems, microgrids, land management and agricultural practices. Lack of transparency has presented reporting challenges for these types of projects, and they are fraught with inefficiencies. The fintech revolution is changing this situation rapidly, with financial technology such as MPESA[54] paving the way for digitisation of financial records in developing economies. Now banks and fintechs such as Eversend[55] and hiveonline, are creating blockchain based value chain audit trails in developing economies at the lowest level, providing opportunities for full traceability of Use of Proceeds in projects across broad communities of primary producers, all the way to the ultimate beneficiary.



Project design of an 'aggregation of assets' bond

In today's regulatory climate, and with the currently available technology, it is already possible to issue a Green Bond employing both the approaches used today by banks, and some of the additional opportunities offered by blockchain technology described in this study. This illustrative example describes how such a project could be structured and funded.

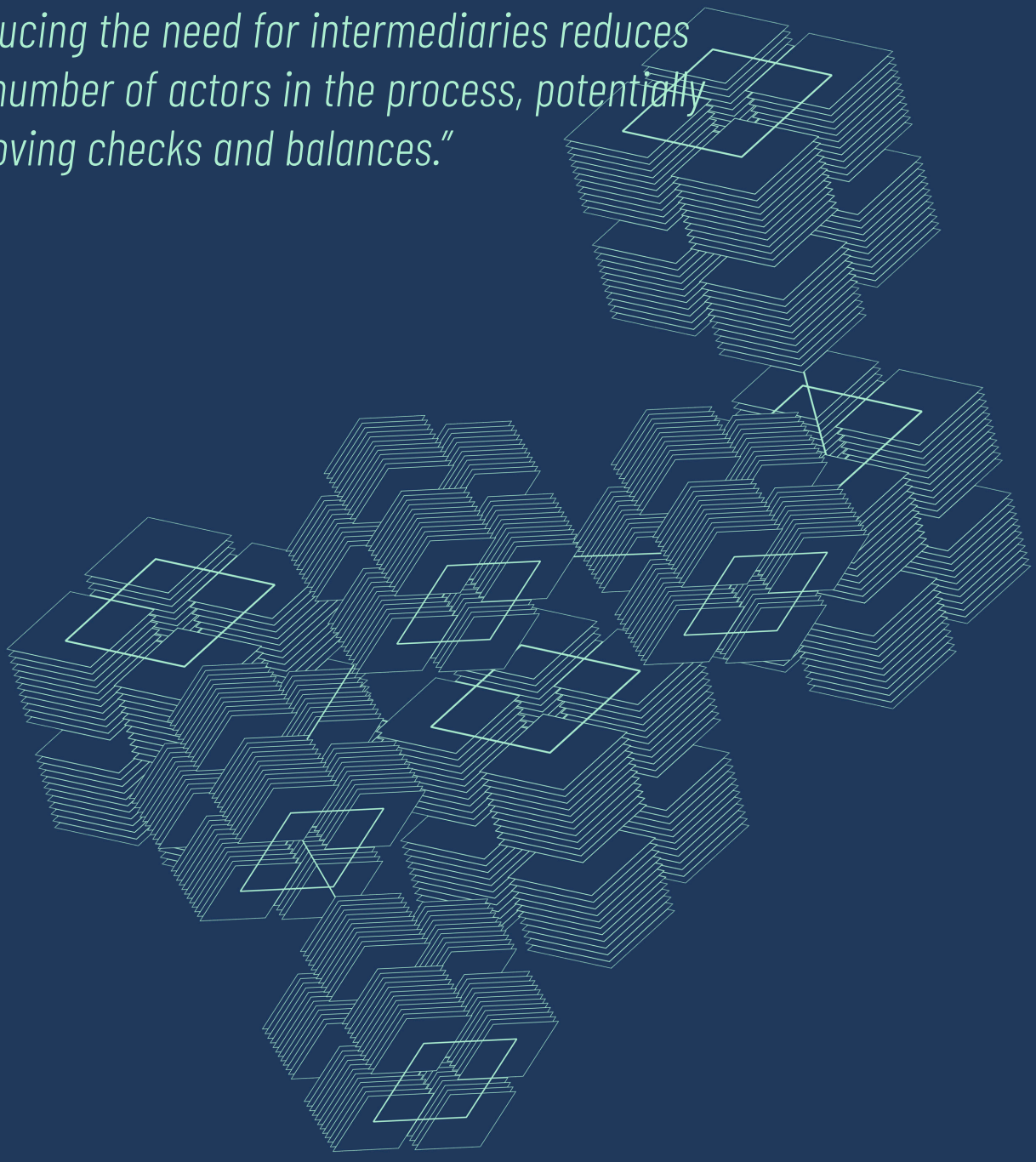
- **Digital asset friendly developing country** target e.g. Philippines, Madagascar, Kenya
- **Aggregation of small projects** e.g. solar microgrids
- **Returns based on energy sales** (microgrids)
- **Presented as community loans aggregated to bond**
- **Issued by development bank** in partnership with NGO and commercial bank with DLT and Green Bond experience
- **Validated by third party**
- **Private, Permissioned blockchain** issues and brokers bond with bank-issued stablecoin for settlement of investment and coupons
- **Standard investor whitelisting** for primary issuance
- **Securitised Token Offering** on secondary market over CH or other STO compliant exchange with crypto or stablecoin settlement (including exchange to fiat)
- **Full or partial use of Bank issued Stablecoins** to exchange with Community Stablecoin for seeding local activities such as build, community loans for Use of Proceeds traceability
- **Use of tokens for Proof of Impact -** shows investors in real time when sustainability targets are achieved
- **Project stablecoin or asset token exchangeable with Proof of Impact tokens** to incentivise sustainable community behaviours and seed community savings schemes
- **Community savings schemes run on stablecoin** to encourage sustainable financial behaviours and provide community guarantee for interest payments / coupons

Using a private, permissioned blockchain for asset management, but issuing secondary instruments on a public exchange allows for appropriate levels of control, privacy and accessibility/visibility at different stages of the bond.

This chapter has described the immediate and future opportunities offered for market innovation in Green Bonds, with a wider range of projects in developing economies and beyond. Building on these opportunities towards a practical implementation of the technology in a real project is the next step. However, as the opportunities are implemented, it will be important to be aware of, and to mitigate, the risks inherent to the transition towards the new paradigm.

PART 5:
RISKS OF APPLYING DLT TO GREEN BONDS

"Reducing the need for intermediaries reduces the number of actors in the process, potentially removing checks and balances."



Risks of applying DLT to Green Bonds

Progressing development of financial products using technology that is powerful but still evolving presents risks both in stability and lack of defined standards. Regulations were designed before the new paradigm of guaranteed outcomes and full chain auditability was available, so offer protections that now create challenges and redundancy. There is a lack of clarity about how the newly flexible instruments will reach their market and how that market will interact with them. None of these risks present critical barriers to further development but must be acknowledged.

Risks associated with the transition

Current platforms are isolated and largely "home-grown" within banks; however, at scale **it will be important for platforms to be interoperable.** DLT is evolving rapidly and faces key challenges such as the trade-off between accessibility / decentralisation, authentication and scale. New platforms with potential to supersede classical DLT blockchains by providing greater security, decentralisation and scale are emerging, but long-term likely standard is hard to predict. This will likely slow the pace of scale into tokenised securities by large institutions, who prefer more certain outcomes.

Accessibility to most Green Bonds is restricted today to **pre-selected investors**, with expensive processes needed for exchange listing. Proprietary bank platforms and blockchain exchanges both have limited reach to investors, so new channels are needed to reach new types of investors.

Smart contracts written to the blockchain can't be altered, so when conditions meet the business rules encoded in them, they will execute. A lack of thorough analysis has in the past led to some well publicised failures, where **code weaknesses** have been exploited by bad actors[56].

Reducing the need for intermediaries reduces the number of actors in the process, potentially removing checks and balances. Regulators and validators need to have clear visibility of the logic and conditions driving instruments to ensure standards are being upheld.

Risk of existing regulations preventing development

Regulations designed to protect investors, such as the custody issue identified during the World Bank/CBA issuance, may prevent participation in bonds over blockchain. Participating banks may follow existing rules short term, however for markets to be efficient, some regulations need to evolve.

Unlike national currencies issued by banks, bank-issued coin is not yet guaranteed by central banks and is therefore subject to the bank's risk rather than to the risk of the national currency. Public Stablecoins such as DAI are also not guaranteed by any central bank.

At scale, movement of value through blockchain reduces liquidity requirements for large corporates and banks, which may impact the distribution of money in an economy and ultimately the need for money supply in a national economy, with implications for inflation, pricing and labour.

Currency stability considerations in illiquid monetary systems

Stablecoin pegged to a stable currency may be attractive for projects in countries with poorly performing currencies, with potential to divert wealth from illiquid currencies into the more stable Stablecoin. This could further destabilise illiquid currencies with a negative impact on the economies of the issuing countries.

GDPR and right to be forgotten

Unlike other data storage blockchains are designed to maintain historical records, which means any data stored on it may be available, in theory, in perpetuity. The EU's General Data Protection Regulation[57] (GDPR) includes a "Right to be Forgotten" where individuals have a right, under certain circumstances, for data about them to be removed. New protocols such as Hedera Hashgraph have addressed this[58], but it's important when using public blockchains like Ethereum to design with this in mind using off-chain personal data.

Personal data on blockchain

Aside from GDPR, the emerging nature of the technology, the permanent nature of blockchain records and the transparency of records all mean any personal data which may identify an individual as being linked to an activity or asset, should be written to it with caution.

These risks could present challenges to the evolving blockchain Bond and Green Bond landscape, if not sufficiently mitigated or addressed. As projects are structured, they must be taken into account, however, none of these should prevent progress continuing and adoption of the technology more deeply into the Green Bond process.

PART 6: CONCLUSION

"Markets are immature and technology is still evolving, however the time is right, and the need is urgent, to progress to the next stage."

Conclusion

Blockchain and adjacent technologies offer great opportunities for more efficient bond markets, however the opportunities offered for Green Bonds in increasing investor confidence, facilitating wider capital flows and reducing the cost of reporting are even more significant. Adoption of DLT will enable Green Bonds to reach and create new markets at both ends of the investment pipeline. Markets are immature and technology is still evolving, however the time is right, and the need is urgent, to progress to the next stage.

While general bond markets can benefit from the efficiencies offered by blockchain, existing practices are deeply embedded and will take some time to evolve. The research for this study has shown that the unique challenges of Proof of Impact and validation specific to Green Bonds are ones to which DLT solutions are well adapted. Existing solutions are already tracking Proof of Impact for non-bond projects and can be rapidly adopted, to demonstrate the opportunity offered.

It is essential to progress rapidly to practical projects which exploit DLT and adjacent technologies, to increase funding for projects combating climate change and supporting community infrastructure in frontier countries. Despite multiple barriers and the evolving nature of the technology, the components needed to move to the next stage are in place. Financial institutions are well positioned to drive this action within their existing sustainable investment portfolios, and must take responsibility for doing so. Markets where corruption or instability present a challenge to investors are disproportionately in need of funding for sustainable infrastructure and community development.

The general bond market is still dominated by traditional practices; while blockchain technology has been used to successfully issue bonds, the very small number of projects and low value relative to general markets has kept these as a pilot, experimental or niche activity within the banks. Security Tokens are being offered on blockchain exchanges, but to date have only reached a limited market. Regulations typically lag innovation and will need to develop before institutional investors can fully benefit from the opportunities DLT offers.

It is unlikely that all institutional investors will rapidly adapt to new markets, however those engaged as investors and issuers in the pilots have had a positive experience and they, and others, will likely continue to engage as pilots grow. Cost reduction opportunities for issuers are very significant and as markets mature, offer wide opportunity to expand the scope of bond issuances to many smaller and more niche projects. Traditional exchanges are now beginning to offer Security Tokens, thereby opening up traditional markets to the new paradigm.

Banks have traditionally been walled gardens, but blockchain technology initiatives have engaged them in collaborative projects. DLT is a poor fit with traditional centralised models, which means adoption in general markets, still heavily centralised, will be slow, but with the opportunity to reduce costs and improve investor communications, issuers are likely to drive the adoption of plug-and-play solutions as they emerge. Banks have an opportunity to support this by collaborating on cross-industry solutions and further pilots, which can be supported by the growth of security specific blockchain platforms being built by financial technology companies.

In conclusion, the tools to move forward and extend the reach of Green Bond financing are in place; the technology is new but has been demonstrated to work. While it continues to evolve, institutions can grasp this opportunity to apply it to creating greater efficiencies, greater confidence, new markets and new sources of capital for the Sustainable Development Goals.

ANNEX

- Blockchain: A New Bond Toolbox
- Methodology
- Legal and Regulatory Limitations of the Report
- Stablecoin types
- Benefits of the technology
- Debt Products issued with blockchain
- Other relevant projects

ANNEX 1

Blockchain: A New Bond Toolbox

Blockchain is paving the way for fundamental changes in the bond market. This distributed ledger technology can significantly change relations between bond market participants. Self-executing smart contracts can automate transfer of assets, settlement, auditing and payments whilst combining with Internet of Things (IoT) and machine learning to automatically capture data from the real economy.

Distributed Ledger Technology (DLT)

Blockchain can transform how multiple actors, such as those engaged in a bond issuance process, collaborate. Blockchain technology[59] is based on **Distributed Ledgers**, where the ledger of transactions is replicated on all authorised digital devices on a network (nodes). A **node** in a Distributed Ledger is the basic computing unit of a distributed network, such as a computer, phone or other digital device. All participants in the network can see additions to the ledger in real time.

In a blockchain, new transactions are added to a "block", which is validated and appended to the chain of previous blocks with a cryptographic key, based on previous blocks and the new transactions. The whole chain of blocks of transactions is then broadcast to every node on the network. That means that changing or overwriting historical transactions would require all copies to be overwritten simultaneously or for the cryptography to be reversed, which is today computationally impossible.

To ensure a continuously synchronised distributed ledger a number of protocols and tools are used. These include **cryptographic tools** and **consensus protocols** to control the movement of **digital assets**.

- **Cryptographic tools:** Participants proposing changes to the ledger, authenticate themselves by using their cryptographic digital signatures. Transactions (in blocks for blockchains) are added to the Distributed Ledger signed by cryptographic keys, and validators will use cryptographic tools to verify whether the participants have the credentials to act.

- **Consensus protocols**[60]**:** Algorithmic processes by which the nodes agree on a common state of the ledger based on rules that have been agreed by all parties, encoded into the technology. Once transactions are recorded, they can't be altered.

- **Digital assets**[61]**:** Digital representations of value or things, uniquely identified and written to the blockchain with ownership validated by a cryptographic record.

Distribution across nodes creates resilience (the network can still operate if nodes are down) and transparency (full transaction history is visible). The wider and more **public** (or **permissionless**) the network, the more resilient and transparent it is, which allows many parties to access information, but requires increased "trustless" consensus such as proof of work or proof of stake. For private, closed networks only opened to **permissioned** participants, faster and less robust consensus can be used.

Ledger Design Options

Venturing into issuing Green Bonds on a blockchain requires decisions about which type of DLT to use and/or whether to build one's own DLT software. Ledgers can be classified as shown in the diagram as **permissionless** (the two squares on the left-hand side) or **permissioned** (the right-hand side).

Permissionless public blockchains

The original Bitcoin blockchain[62], is an **open source codebase** owned by nobody, designed to create a completely borderless currency with no controlling authority, making it censorship resistant. Participants (called miners) process transactions with a reward of Bitcoin to verify a "**block**" of transactions in a process called "proof of work", which creates a tamper-resistant network. Blocks are authorised via a **consensus protocol**, where more than half the network agrees they are valid.

The advantages of a fully distributed, **permissionless ledger** is that it is a public system with no risk of a central authority controlling it, so it's theoretically democratic. The main disadvantages are that it's slow (by design) so transaction throughput is limited and energy intensive.

Another type of **public blockchain** is **semi-permissioned**, where anyone meeting certain rules can join the community, such as **Stellar**. This lacks the anonymity of the public permissionless blockchain but has the advantage of an algorithmic approach to mining which is much faster and less energy intensive.

Permissioned, Consortium and Private DLTs

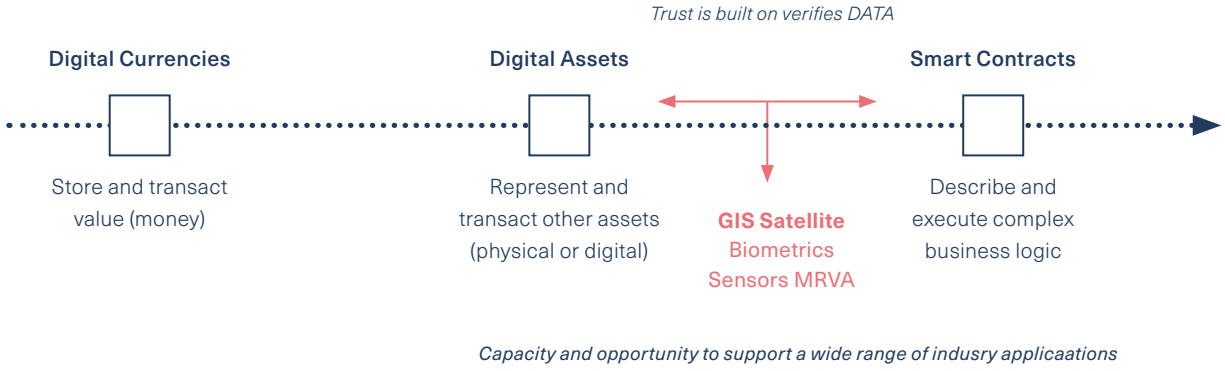
Permissioned blockchains can operate much faster than public permissionless blockchains, but lack both anonymity and wide distribution. Public, permissioned blockchains - also known as **Consortiums**, where all nodes are owned by trusted actors who establish the architecture, can be accessed by anyone, but only a trusted set of network participants can initiate/validate transactions.

Fully permissioned **Private Distributed Ledgers** can be used by a Consortium, typically with each actor owning a **node** (or nodes), such as **R3's Corda**, designed for the Banking industry, or by a single organisation. An advantage of all nodes being owned by trusted actors is that pre-defined consensus rules can be used for virtually instant confirmation of transactions with negligible energy impact. They can transfer value between entities or track assets through a supply chain, with confidence that the same asset has been logged at every point from start to finish.

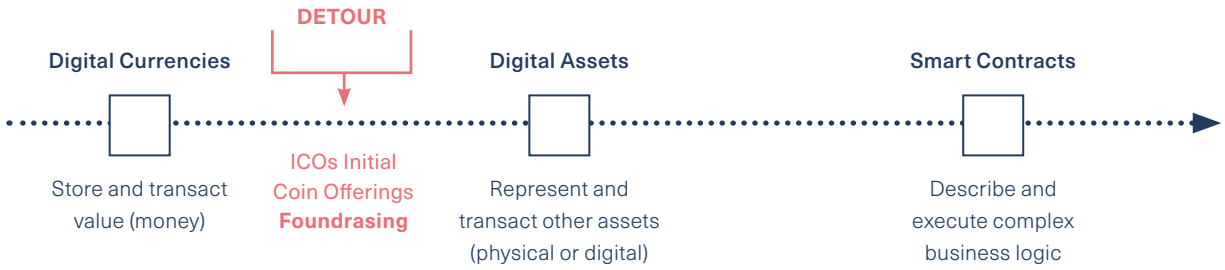
Smart Contracts

A **smart contract** is a computerized transaction protocol written to a blockchain that can be made to automatically executes based on business rules and the authority of the digital signatories. A **smart contract** (or chaincode in Hyperledger Fabric, States[63] in R3 Corda) can react to real time data to execute the terms of an agreement, without requiring manual intervention. It can also transfer digital assets between participants in a **DLT** network once predetermined criteria are met. Smart contracts have been implemented in various ways for different **DLTs**.

Evolution of Blockchain Protocols



The ICO Detour



Adopted from Katherine Foster and BLOC 2019

Digital Assets

There are thousands of **cryptographic**, or **digital assets** in existence, like well-known cryptocurrencies such as Bitcoin or Ether, tokens and coins such as those issued in ICOs and digital assets representing assets like property, diamonds or fine wines. However, no *internationally recognised classification exists*. This study limits itself to a description of only those categories of **digital assets** including tokens with immediate potential to either automate or innovate specific steps in a Green Bond process.

1. **Cryptocurrencies:** Cryptographic representations of value not backed by any asset, used as a means of payment or of value transfer across a public blockchain, such as Bitcoin, Ether or Stellar Lumens.

2. **Utility Tokens:** Provides digital access to a blockchain based application or service. Used to exchange information within a blockchain system; have been issued through ICOs for fundraising.

3. **Asset Tokens:** Represent (usually physical) assets such as produce, artwork or natural capital. Often considered to be non-fungible tokens.

4. **Security Tokens:** asset tokens representing a debt or equity claim on the issuer, analogous to equities, bonds or derivatives. Some jurisdictions (e.g. Switzerland) also classify physical asset tokens as a security.

5. **Stablecoins:** a token which maintains stability by tracking the value of a fiat currency such as USD or EUR, using smart contracts to manage the relative value based on a blockchain network. The best known is Tether, but the most popular Stablecoin[64] as of Q3 2019 is MakerDAO's DAI[65], based on Ethereum, which tracks the USD. DAI uses logic embedded in smart contracts to maintain the value equal to 1 DAI=1 USD.

Adjacent Technologies

An **adjacent technology** is one that offers to improve an existing technology, for example a coffee grinder could be adjacent to a coffee percolator. In the case of the deployment of DLT in the Green Bond market, the most relevant adjacent technologies include Internet of Things **(or IoT) devices** such intelligent chips, sensors, QR codes and satellites, and **machine learning** or advanced analytics.

Bridging to the physical world

Green, and other **Uses of Proceeds Bonds**, require data about the performance of an underlying green asset. Manual data collection introduces the risk of data quality, limits digitisation and adds cost.

Using adjacent technologies in combination with DLT opens the opportunity for **automated data harvesting**. A class of physical devices is also emerging which embeds blockchain capabilities into sensors - for example, the Solara Hardware Module©[66] in which blockchain enabled chips that collect information from solar panels about energy produced and the data is automatically communicated using tokens on a blockchain. The token automatically collects key information creating a permanent, tamper-proof "witness proof[67]" while creating a **shared digital view** of the history and performance of underlying assets visible to all participants in the DLT network, who could be investors in the asset.

Tracking physical assets on a blockchain requires integration of bridges between the neat digital and messy physical worlds, so that each asset in the real economy is represented by a blockchain '**digital twin**'. A digital twin is a digital representation in data on a blockchain, of a real asset such as a windmill, a building or a solar cell. These data can be provided by using labelling devices as simple as **QR codes**, through **smart tags**, all the way to sophisticated dedicated sensors. This in turn provides confidence that the asset has not been tampered with or adulterated, critical to many types of produce and a key benefit to reporting to stakeholders such as purchasers or investors.
By automating these processes, it's also possible to provide real-time reporting and visual evidence of processes as assets have been transformed, for example by transmitting data about Oxygen production of a forest in real time, or showing a photo of a food product in the aggregation or transformation process, on a stakeholder's mobile phone.

Using the toolbox for Green Bonds

Blockchain technology provides multiple tools which can be applied to Green Bonds, to reduce friction, increase transparency and provide new opportunities for distribution. The standard bond process includes many processes where smart contracts can add speed and confidence through automation, and Green Bonds offer further opportunities to apply the technology to Use of Proceeds and Proof of Impact, especially when combined with adjacent technologies supporting value chain authentication such as IoT.

ANNEX 2
Methodology

A Secondary literature review is not possible as the blockchain powered bond market is currently in the early stages of unfolding. This research has examined existing blockchain bond projects, relevant industry projects, and projects exploring applications of blockchain to sustainability projects. The authors have drawn on past research and conducted literature reviews with a focus on developments over 2018-2019, when most of the relevant activity has taken place. Interviews were conducted with people engaged in:

- Blockchain based bonds issued by banks;
- Blockchain platforms issuing debt products;
- Green bonds - issuance and third-party validation;
- Sustainability projects using blockchain for Proof of Impact.

Statistical analysis was conducted based on literature reviews and some material from these interviews.

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ANNEX 3

Legal and Regulatory Limitations of the Report

SDFA research highlighted that regulators need to be engaged to fully '**move the market**'. Bonds issued through on-chain render processes such as custody and triple-checking unnecessary, however as bonds, they are bound by existing regulations. For example, in Australia, pension fund investment restrictions require that assets are held at a bona fide custodian, so an institutional investor was prevented from participating in the World Bank and CBA's bond-i. Other banks chose to abide by custody rulings, adding otherwise unnecessary friction and cost.

Complying with the issuing jurisdiction's custodianship rules is required, even though the existence of the contract in transparent and tamper-proof form renders it unnecessary. In some jurisdictions, it's still necessary to register and store a paper copy of the bond, although this is becoming less common as governments and regulators recognise the strength of digital copies and signatures. These processes will require regulatory intervention to prevent them causing unnecessary friction and duplication of effort in the future.

It is necessary, and will remain necessary, to ensure that any bond issued on-chain is legally sound, so some existing processes must remain in place, at least until large areas of the market and legal profession are also on chain. These include areas like KYC and AML (Anti-Money Laundering), and validating that the overall structure of the bond meets regulatory standards.

In some of the cases reviewed in this study, regulators were invited to observe the process through their own node on the issuing blockchain but rejected the offer. Hosting a node would give regulators direct access to real-time information about the bond, without having to depend on reporting or innovate how regulatory oversight is conducted. However, regulations and internal processes will need to be updated.

Restrictions on the use of, and inconsistency in the definition of, digital assets from country to country, has contributed to the lack of progress in adopting Stablecoin-style bank-issued Cash on Ledger for settlement, outside a few examples.

ANNEX 4

Stablecoin types[68]

ISSUER	CURRENCY	COLLATERAL	RISK
Bank, e.g. JPMCoin "Cash on Ledger"	USD, EUR, other stable fiat currencies	Fractional Reserve Limits, i.e. no collateral requirement but offset against issuance of standard currency	Inherits risk of issuing bank
Central Bank, E.G. PBOC[69]	National currency	n/a, issued under national monetary policy money supply limits	Inherits risk of national currency
Consortium of banks e.g. Fnality	USD, CAD, GBP, EUR, YEN	Cash reserve at central banks (Fnality)	Partially that of bank but supported by national currency thanks to cash reserve
Non-bank Fintech (fiat backed), e.g. Tether	National currency	Cash reserve at central banks (Fnality)	Inherits risk of holding commercial bank, however (as with Tether) that requires transparency to maintain confidence
Non-bank Fintech (collateral backed), e.g. MakerDAO DAI	USD, EUR, other stable currencies	Collateral reserve held as digital assets	Managed by Fintech and governed by Board, Foundation etc
Non-bank Fintech (fiat backed, multiple currency) e.g. Libra	USD + YEN + CHF + GBP + EUR...	Cash reserve held in Swiss commercial bank	Inherits risk of holding commercial bank BUT not clear how currency valuation and fluctuations would be managed

ANNEX 5

Benefits of the technology

BLOCKCHAIN ASSET	PROCESS	BENEFIT	RISKS/BARRIERS
Security Token	Issuance	Standardised Regulatory transparency Can issue any number in small units with little cost	Multiple processes still required for compliance Legal review necessary
Security Token	Bidding process	Full transparency Automated bidding and closing	Listing still on traditional listings platforms
Security Token	Distribution	Straight through transfer of ownership Resilient, immutable	Regulations are uneven but maturing rapidly
Cryptocurrency	Investment	Asset class that may accrue value Fully distributed	Volatility Lack of consensus on asset class Anonymised wallet holders
Stablecoin	Payment, settlement	Straight through transfer of ownership Instant settlement, reduced risk	Inherits risk of organisation that guarantees it Lack of consensus on asset class
Asset Token	Distribution of assets Registration	Straight through transfer of ownership Audit trail	Lack of consensus on asset class
Utility Token	Movement of data Registration	Audit trail Can be used to trigger “real” asset movements under agreed rules	No real world value

ANNEX 6

Debt Products issued with blockchain

DATE	INSTRUMENT	VALUE	ORGANISATION	PROCESSES	BLOCKCHAIN
11/07/2019	Commercial Paper (CP)	USD 15m	YES Bank	issuance and redemption	R3 Corda
TBD	European Commercial Paper (ECP)	TBAding and closing	European Investment Bank, Euroclear, Banco Santander & EY	End-to-end blockchain solution for the issuance and settlement of European Commercial Paper	R3 Corda
18/04/2019	Covered Bond	EUR 100m	Société Générale	Issuance, directly offered as STO on public blockchain but Société Générale was sole investor	Ethereum (public)
Feb 2019	Structured Green Bond	UR 35m	Banco Bilbao Vizcaya Argentaria (BBVA)	Issuance Registration	Hyperledger Fabric (bid process) Ethereum testnet
2018	Various loan products	EUR 860m	BBVA	Issuance Registration	Hyperledger Fabric (bid process) Ethereum testnet
January 2019	Commercial Paper	€100,000	Continental, Commerzbank and Siemens	Structuring, Issuance, Payments and Settlements	R3 Corda
15/08/2018	fixed income issuance	Canadian Depository for Securities (CDS) $250MM	Bank of Montreal (BMO) Capital Markets	validation	open source blockchain infrastructure with the goal of testing a next generation settlement system
TBD	NBC debt issuance	USD 150M	National Bank of Canada (NBC) and J.P. Morgan	origination, settlement, interest rate payments and other processes	Quorum based on Ethereum blockchain, developed by JP Morgan
10/08/2018	Sustainable Bond	A$110 million	WorldBank and Commonwealth Bank of Australia (CBA)	Structuring and Issuance Audit trail	Bond-i - Private Permissioned version of Ethereum blockchain
TBD	Bitcoin (BTC) Bond		Argento and LBX (London crytptocurrency exchange)		Bitcoin Blockchain

Other relevant projects

ORGANISATION	PRODUCT	TECHNOLOGY	APPLICATION
HQLA-x	HQLA-x	R3 Corda	A financial technology innovation firm that leverages R3's distributed ledger technology, to deliver liquidity management and collateral management solutions for institutional clients in the global securities financing markets.
HSBC, ING, NatWest, BNP Paribas, Standard Chartered, Bangkok Bank, BBVA, Intesa Sanpaolo, Mizuho, Scotiabank, SEB and US Bank	Voltron	R3 Corda	An open co-operative initiative delivering a blockchain based open industry platform to create, exchange, approve, and issue Letters of Credit on Corda
BitBond	The Bitbond Token (BB1)	Stellar	Security Token
Provenance.io	Provenance.io	In house based on Hyperledger Fabric IIRC	A permissioned, proof of stake protocol that acts as a global ledger, registry and exchange across assets and markets
we.trade	we.trade	IBM Blockchain Platform using Hyperledger Fabric	Smart Contracts

References

[1] www.sustainabledigitalfinance.org

[2] www.climatebonds.net/files/reports/cbi_gbm _final_032019_web.pdf

[3] www.worldbank.org/en/news/speech/2018/05/15/leveraging-innovative-finance-for-realizing-the-sustainable-development-goals

[5] www.ledgerinsights.com/bbva-blockchain-structured-bond-mapfre/

[6] World Bank and CBA Press Release

[7] http://fintechnews.sg/30743/blockchain/the-world-bank-blockchain-secondary-marketplace-bond-i/?fbclid=IwAR37CdWtdVADns4mt-OnlUzDG-tCSKi

[8] https://www.ledgerinsights.com/bbva-blockchain-structured-bond-mapfre/

[9] http://cbonds.com/news/item/1088565

[10] https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op230~d57946be3b.en.pdf?321f6bf14960e6f604725be5a466957b

[11] https://www.coindesk.com/fnality-utility-settlement-coin-central-bank-token-blockchain

[12] https://info.binance.com/en/research/marketresearch/CBDC.html#fn14

[13] https://www.coindesk.com/french-lender-societe-generale-issues-112-million-bond-on-ethereum

[14] https://newsroom.bmo.com/2018-08-15-BMO-Capital-Markets-Launches-First-of-its-Kind-Blockchain-Pilot-to-Mirror-Canadian-Dollar-Fixed-Income-Issuance-Transaction-with-Ontario-Teachers

[15] https://www.ledgerinsights.com/nomura-nri-corporate-bond-blockchain/

[16] https://token.security/stn/listing/six-swiss-exchange/

[17] https://www.oekb.at/en/oekb-group/presse/pressemitteilungen/2018/blockchain-einsatz-bei-bundesanleihebegebungen-gestartet.html

[18] https://cointelegraph.com/news/worlds-first-zero-fiat-bitcoin-bond-now-available-on-bloomberg-terminal

[19] https://www.bitbondsto.com/files/bitbond-sto-lightpaper.pdf

[20] https://www.fintech.finance/01-news/the-bitbond-token-bb1-receives-isin-shortly-before-the-end-of-the-offer-period/

[21] https://www.bitbondsto.com/files/bitbond-sto-prospectus.pdf

[22] https://www.investopedia.com/news/what-erc20-and-what-does-it-mean-ethereum/

[23] https://thetokenist.io/security-token-study-64-successful-stos-raised-nearly-1-billion-so-far-trends-suggest-significant-growth/

[24] https://thetokenist.io/luxembourg-passes-new-bill-giving-tokenized-securities-official-legal-status/

[25] https://www.abbl.lu/2019/03/06/luxembourg-stock-exchange-wins-green-bond-pioneer-award-from-cbi/

[26] https://www.ampliv.io/all-about-sto-regulations-in-germany/

[27] https://bitbondsto.com

[28] https://www.ft.com/content/06c2eaf4-9e64-11e9-b8ce-8b459ed04726

[29] https://cms.law/en/INT/Expert-Guides/CMS-Expert-Guide-to-Security-Token-Offerings/Switzerland

[30] https://www.six-group.com/exchanges/bonds/green/green_bonds_list_fr.html

[31] https://www.worldbank.org/en/news/press-release/2018/10/29/seychelles-launches-worlds-first-sovereign-blue-bond

[32] https://coinlaw.io/security-tokens-are-securities-says-mauritian-financial-watchdog/

[33] https://www.un-page.org/mauritius-embark-ambitious-green-bond-strategy

[34] https://www.gtlaw.com/en/insights/2019/7/new-regulations-in-japan-on-security-token-offerings

[35] https://www.climatebonds.net/resources/reports/japan-green-finance-state-market-2018

References

[36] https://www.cnplaw.com/security-token-offerings-in-singapore/?utm_source=Mondaq&utm_medium=syndication&utm_campaign=View-Original

[37] https://www.adb.org/publications/green-finance-singapore-barriers-and-solutions

[38] https://stmarket.co/en/news/177/Philippines-Release-STO-Regulatory-Framework.html

[39] https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/impact-stories/green-bond-philippines

[40] https://www.transparency.org/cpi2018

[41] https://www.marketsmedia.com/for-bonds-on-the-blockchain-start-at-the-origin/

[42] https://medium.com/jibrel-network/sukuk-bonds-on-the-blockchain-9b5bf02778d0

[43] https://www.accenture.com/_acnmedia/accenture/conversion-assets/dotcom/documents/global/pdf/consulting/accenture-banking-on-blockchain.pdf#zoom=50

[44] https://www.accountingtools.com/articles/how-do-i-account-for-bond-issue-costs.html

[45] http://unepinquiry.org/wp-content/uploads/2016/09/6_Green_Bonds_Country_Experiences_Barriers_and_Options.pdf

[46] https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/June-2018/Green-Bond-Principles---June-2018-140618-WEB.pdf

[47] https://techcrunch.com/2019/03/15/the-inevitability-of-tokenized-data/

[48] https://www.undp.org/content/undp/en/home/blog/2019/adopting-a-cedar-tree-and-bringing-diaspora-money-home.html

[49] https://www.globalmangrove.org/

[50] https://fishcoin.co/

[51] https://openknowledge.worldbank.org/bitstream/handle/10986/29499/124402-WP-Blockchainandemergingdigitaltechnologiesforenhancing-postclimatemarkets-PUBLIC.pdf?sequence=1&isAllowed=y

[52] Using Bank-issued coin reduces settlement risk by over 99%#, eliminates counterparty risk and elapsed time, and significantly reduces costs. It can be used internally in the bank or within a network shared by corporate clients.

[53] http://blockchainbond.io/

[54] MPESA

[55] Eversend

[56] https://www.coindesk.com/understanding-dao-hack-journalists

[57] General Data Protection Regulation

[58] https://www.hedera.com/file-service

[59] https://www.coindesk.com/information/what-is-the-difference-blockchain-and-database

[60] https://www.coindesk.com/vitalik-buterin-on-public-and-private-blockchains

[60] https://101blockchains.com/consensus-algorithms-blockchain/

[61] https://medium.com/datadriveninvestor/basics-of-crypto-digital-assets-70cfe32e357c

[62] Bitcoin: A Peer-to-Peer Electronic Cash System - Bitcoin.org

[63] https://docs.corda.net/key-concepts-states.html

[64] https://news.bitcoin.com/an-in-depth-look-at-ethereums-maker-and-the-Stablecoin-dai/

[65] MakerDAO DAI

[66] Solara hardware module

[67] witness proof

[68] https://www.cbinsights.com/research/report/what-are-Stablecoins/

[69] PBOC CBDC

[70] https://www.coindesk.com/fnality-utility-settlement-coin-central-bank-token-blockchain

[71] Tether Stablecoin

[72] https://techcrunch.com/2019/06/18/facebook-libra/