BIS Innovation Hub

Hong Kong Centre

A prototype for green bond tokenisation by the Liberty Consortium

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Contents

In collaboration with:

Abstract

In many countries, issuing and investing in bonds can be cumbersome and complex, involving numerous steps and parties, and typically requiring a considerable financial commitment from the investor. For those investing in environmentally friendly projects, there is uncertainty about whether the bond issuer is delivering the positive green impact it committed to at issuance. Also, there are typically no liquid and transparent secondary markets for retail investors. Genesis, the BIS Innovation Hub's first green finance project, explores the green art of the possible through combining blockchain, smart contracts, internet-of-things, and digital assets. Together with six partners, the project achieved two prototypes that bring to life the vision that an investor can download an app and invest any amount into safe government bonds, which will develop a green project; over the bond's lifetime, the investor can not only see accrued interest, but also track in real time how much clean energy is being generated, and the consequent reduction in CO_2 emissions linked to the investment; further, the investor can sell the bonds in a transparent market. The present report shows the technical infrastructure of the prototype created by the Liberty Consortium. This report was drafted with the technical inputs of The Liberty Consortium. As such, the views given in this report are not necessarily those of the BIS or the HKMA. The present report is a sister report to Project Genesis – Report 1 "A vision for technology-driven green finance".

Executive Summary

Genesis, the BIS Innovation Hub's first green finance project in collaboration with the Hong Kong Monetary Authority (HKMA), explores the technological feasibility and opportunities of green bond tokenisation.[1] This report shows the prototype produced by the Liberty Consortium, comprised of Standard Chartered Bank, SC Ventures,[2] and Shareable Asset[3] (referred to as the Liberty prototype or the prototype).

The Liberty prototype develops a technology sample to concept-test a government issued digital asset for the retail market in Hong Kong. The prototype aims to improve investor participation by streamlining the overall bond issuance and lifecycle processes, allowing direct exchange amongst asset holders,[4] facilitating the tracking of the green impact of invested funds, and allowing a smaller minimum allocation size. The prototype provides technology insights into potential applications for distributed ledger technology, specifically public decentralized ledgers, and how they may be integrated into the existing financial ecosystem within Hong Kong.

The prototype provides a sample process for issuers to issue assets directly to the retail market in an efficient manner, with improvements made to existing process pain points, in particular as it relates to duplicate subscriptions, a prolonged closing period, and an inefficient secondary market. These are addressed by streamlining the investor onboarding process and facilitating a direct payment and settlement process between the issuer and investor. Finally, the prototype has created a proof-of-concept process for direct secondary market exchanges among retail investors, utilizing the underlying ledger infrastructure.

From a technology perspective, the prototype has explored critical path integrations with the existing infrastructure and participants in the Hong Kong market. Of note, this includes integrations with the existing placing institution network and with the Hong Kong Stock Exchange (HKEX). For markets or conditions where the integrations are not available, the prototype provides a process for managing these aspects within just the prototype itself. This provides insights into how the prototype may be used in other markets outside of Hong Kong, or where it may provide alternative means for achieving similar to superior functionalities.

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[1]   See https://www.bis.org/about/bisih/topics/green_finance/green_bonds.htm and https://www.bis.org/press/p210824.htm.

[2]   The Liberty Consortium Prototype is built on Shareable Asset's blockchain middleware and Capital Markets protocols. Using a fully digital offering, Liberty's goal is to offer a new arrangement between state issuers and their target market, in a way that is more efficient and engaging, while retaining high standards of reliability and safety.

[3]   See https://www.shareableasset.com.

The prototype is also integrated with a green data feed from Allinfra[5] that provides asset performance details to green bondholders over the life of the green bond. This increases transparency, provides greater detail on use of proceeds, and allows for greater certainty regarding green impact of the underlying financing.

The key benefits offered by the Liberty Prototype for Project Genesis or similar issuances:

- Automated and streamlined primary issuance system

- Efficient asset servicing during the life cycle of the bond

- Easier secondary trading for investors and asset holders

- Real time insight into end-investor behaviour and activities

- App-based mobile access for investors

- Low denomination bond issuance

- Decreased transaction costs

- Instant and atomic settlement

- Potentially improved asset liquidity

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5   See https://Allinfra.com/?gclid=EAIaIQobChMIib329bjT8wIV94ZLBR1lgwAYEAAYASAAEgKYWPD_BwE.

1. Functional Overview

The Liberty prototype is designed to explore innovative technology solutions to digitizing the green bond process, enabling issuance directly to retail public. The prototype issuance process is modelled after the existing Hong Kong government retail bond process, which is implemented by the HKMA, but aims to provide efficiencies where possible over the existing process.

This modelled process involves a preparation phase, in which the bond issuance is prepared and legally arranged, a subscription phase, in which prospective investors may apply for the bond, and finally, a closing process, in which the subscription period ends, the bonds are allocated, and effectively issued to investors against payment. Throughout this process, the HKMA works with a few key institutions, known as placing institutions, to manage onboarding and verifying valid investors, submitting subscription requests, and managing and processing the associated payments.

The Liberty prototype enables the issuer to interface directly with investors in a cost effective and streamlined manner. This is done by tokenizing the bond asset, such that it may be distributed directly to investors, and investors themselves are able to hold the bonds directly through their digital wallet. The prototype has proven out and explored several ways to facilitate customer onboarding, process payments, and facilitate secondary market activity. In addition to being able to manage the bond, the prototype provides transparent real-time insight into marketplace activity.

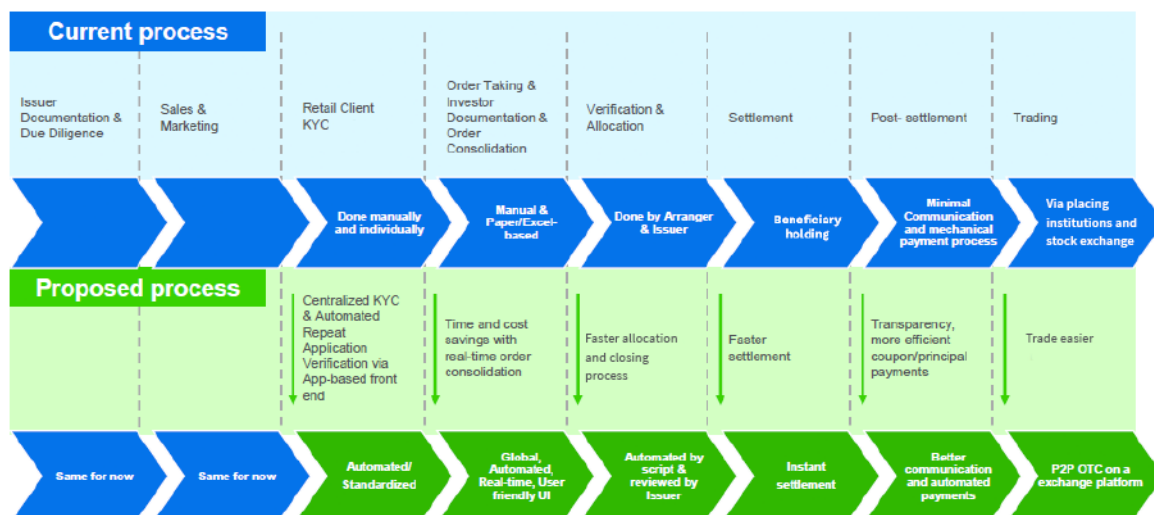*Figure 2: Comparison between the current and proposed processes.*

As shown in Figure 2, the prototype system has automated the application verification by centralising the KYC with an App-based front-end. Thanks to the elimination of escrow processes, the settlement has become faster as well.

The following describes how the Liberty prototype implements the functionality for each of the bond phases.

1.1 Preparation and Issuance

The Liberty prototype is first used after the issuer has conducted the preparation phase. After the issuer has specified the bond terms, typically conducted with assistance from local banks who are serving as co-arrangers, the bond term sheet is finalised and ready for distribution to the public. The term sheet details are captured in the web application, including details such as the maturity length of the bond, the schedule of coupon payments, and how long the initial bond subscription period should be open for. Ultimately, with the details inputted the bond is submitted for internal approval, and the subscription process is initiated on the specified date.

Figure 3: Liberty prototype's bond creation page.

At launch, the distribution of the bond term sheet to the public represents the first interaction between the issuer and the retail market. This, in combination with the bond prospectus and other associated media, is used to communicate key details about the investment offering and motivate prospective investors. Traditionally conducted via placing institutions - local banks and securities brokers who are licensed to sell the bond to the Hong Kong public - the Liberty prototype models has presented and distributed the term sheet and associated materials directly to prospective investors. The prototype is envisioned as the bond placement mobile application, an application designed to be specifically used for the retail-facing bond process. Placing institutions are still encouraged to solicit investors from their customer base, as they do today in the current system, and such efforts are rewarded through a referral fee system.
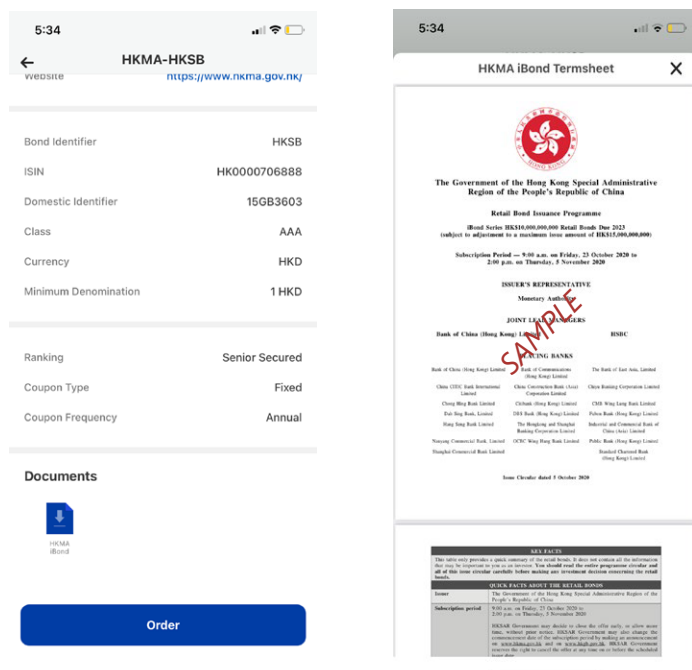
Figure 3: Sample of HKMA iBond Termsheet.

1.2 Customer Onboarding

In concept, the retail green bond is designed to be available to residents of the HKSAR. Put simply, anyone who holds a valid Hong Kong Identity (ID) card can invest the green asset.

In the existing process, customers are onboarded via the placing institutions, where customers are typically registered with securities accounts and have been processed by the institutions know-your-customer (KYC) rules.

In the Liberty prototype, KYC is a digital process that is handled directly on the bond placement application. Prospective customers can register their information in the application, where they will then proceed through a video-based process that captures their Hong Kong ID and visual proof of their presence (avoiding issues of a doctored or stolen HKID), as shown in Figure 4.

Figure 4: The digital KYC process involving ID upload and visual proof.

For the prototype, the Liberty Consortium explored two additional customer onboarding mechanisms, integrating with the retail utility IAMSmart and leveraging OpenID Connect.

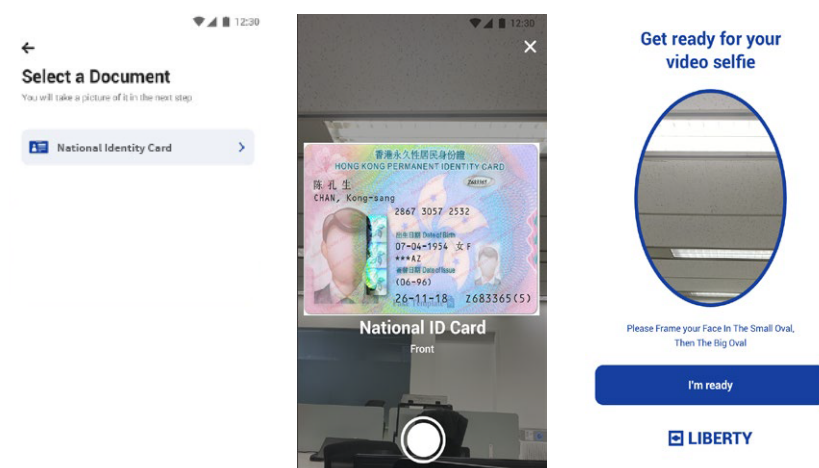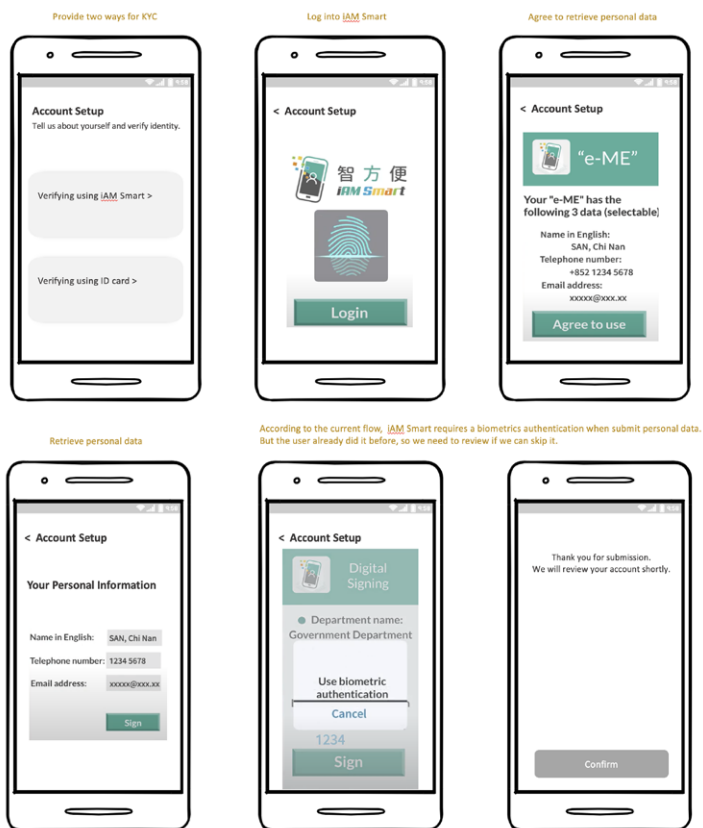IAMSmart is a local Hong Kong utility that allows merchants and service providers to easily verify and onboard Hong Kong customers. Hong Kong residents are able to register in IAMSmart with their personal data and then utilise their IAMSmart account to conduct authorization and authentication activity with other applications.

OpenID Connect (OIDC) is another mechanism for onboarding of customers that would help digitise the onboarding process. OIDC is an authentication and authorization technical standard that specifies how identity information can be shared between many identity providers and digital applications. The OpenID standard is often a recommended practice within open banking initiatives, including in Hong Kong.[6] Using this, customers could leverage their existing bank accounts in Hong Kong to log into the bond placement application. Interested readers can refer to the references herein for more details on OIDC and iAM Smart.
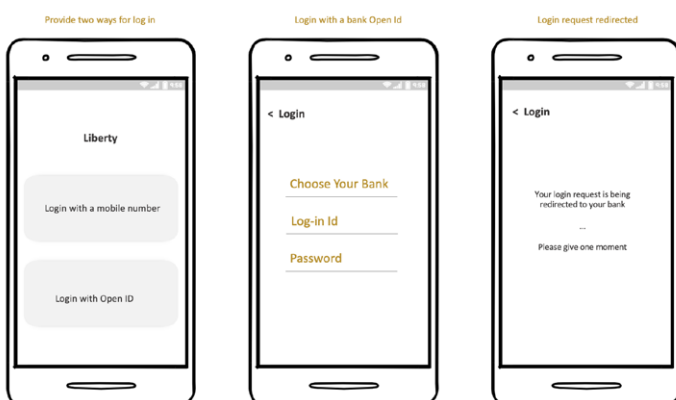

Figure 5: The simulated integration between Liberty prototype with OIDC and iAM SMART.

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6   See https://www.hkma.gov.hk/media/eng/doc/key-functions/ifc/fintech/The_Next_Phase_of_the_Banking_Open_API_Journey.pdf.

In the existing process of retail bond issuance in Hong Kong, the HKMA must deal with the issue of duplicate applications since a customer is able to subscribe for the bonds at multiple placing institutions. This is resolved when the applications are finally consolidated at the end of subscription period and duplicate applications can be identified and handled appropriately. Through the implementation of a single onboarding mechanism, in addition to alternative solutions identified, the duplicate screening issue is effectively resolved.

1.3 Subscription

Once onboarded, the retail investor is able to participate in the subscription phase.

Traditionally, as with most fixed-income assets, the subscription process follows issuer specified rules that dictate to whom and to what amount bonds are allocated. For government issued assets, the focus is on providing a subscription process that is fair and equitable for the government's target investors and while still meeting the funding needs of the bond issuance target. The Liberty prototype is purpose-built to flexibly support a variety of rules-based approaches.

In the prototype, customers participate in the subscription process by placing a request for a specified bond allocation amount. This will correspond with the bond term sheet, which may dictate a minimum allocation size or investment dollar amount as part of the subscription request. Investors are then asked to top-up their wallet from an existing bank account based on the requested allocation amount. These funds are then locked-in, finalizing the investors request, and will ultimately be used to pay for the bond upon closing.

Subscription periods are usually open for a set-period of time in order to allow prospective investors to make their applications. Following end of the subscription period, the bond is issued against payment and the bond asset begins accruing interest for the legal/beneficial owner, the registered investor in the bond asset. In the existing retail bond program, the HKMA aggregates all subscription requests and processes them according to a rulebook based on the original bond terms, the application demand, and other determinant factors. The Liberty prototype models this existing process as it is today. With application requests received directly by the issuer, the allocation amounts can be processed easily using existing internal tools, and in case of oversubscriptions, instruct banks to release the corresponding funds to the customers' wallet immediately.

With a platform that is fully digitally integrated within the issuance process, allowing asset rules and behaviours to be codified up front, and then enforced throughout the assets lifecycle, this allows new rules and subscription processes to be easily created and executed on, with minimal friction between the bond administrators and the bond system operators. This flexibility provides an efficient mechanism for targeting different market segments or different retail bond products to help meet specific issuer goals.

1.4 Allocation, Closing, and Settlement

- (By Business Day)

T-7	T-6	T-5 to T-3	T-2	T (Issue Day)	T+1
Subscription Period end	Placing Blanks Submit Application to HKMA	Verify Repeat Application and Confirm Allocation	Press Release: Issue Size, Total Application and Allocation Result Inform Placing Bank the Allocation Result	Issue	Listing

Table 1: The existing closing process for retail issuance

The subscription phase ends, and the closing phase begins upon the specified date in the term sheet but can be ended early 1or extended based on demand. As mentioned previously, the rules-based subscription process is executed against the received applications. Table 1 summarizes the timeline of the existing closing process for retail issuance in Hong Kong.

As shown in Table 1, the existing process for retail government bonds, seen in Figure 1, there is a seven-day closing period from when the subscription period ends, and the bond ownership is officially settled for the instrument to begin accruing interest on behalf of the investor. This period involves a final confirmation of allocations and a transfer of corresponding cash between the placing institutions, holding money for prospective investors, and the issuer recording ownership of the bonds with the placing institutions, who are then subsequently responsible for recording and registering the individual ownership details of each bond. The Liberty prototype greatly streamlines this process, reducing the closing period to a day, with a direct connection between issuer and investor and a single consolidated order book. The particulars of enhancement are elaborated in the Efficiency Savings section.

In the prototype, the money in the user's wallet, previously locked during the subscription period, is exchanged for a tokenised representation of the bond asset. This tokenised representation means that the asset owner is recognised by their ability to prove that they "hold" the asset. The technical details related to this ownership is offered through the wallet and more details are offered in the Technical Architecture section.

In effect, this means that the transfer of bond ownership, from issuer to investor, and the transfer of cash, from investor to issuer, occurs directly through the platform without any intermediary steps necessary. This allows for a fast and efficient closing process, with reduced operational costs and risks, and an optimal user experience for the retail investor. The technical overview later on provides more details on the wallet and how tokenization works within the platform.

Ultimately, the Liberty prototype allows the closing period to occur in a T+1 fashion, reduced from the existing T+7 settlement window (which includes 2 days of allocation confirmation). While the settlement window can be tightened even further, this time period allows settlement to be validated in an orderly fashion, which is important as the bond will start accruing interest immediately upon final settlement.

1.5 Secondary Market Activity

The Liberty prototype includes a proof-of-concept for enabling secondary trading for the tokenised bonds. The secondary trading could take the form of an independent marketplace within the Liberty platform or in conjunction within an existing secondary market exchange, such as the HKEX. While the existing inflation-linked retail bond launched by the HKSAR Government currently does trade on the HKEX, modelling the green bond as a tokenised asset in Project Genesis introduces both new complexities and new opportunities for secondary market activity.

The Liberty prototype provides a great deal of flexibility on how to accomplish the provision of a secondary market for the tokenised bonds. The Liberty prototype explored the creation of an independent standalone secondary market facilitated between the retail investors. Additionally, the prototype designed and explored the interconnection of the platform to the Hong Kong Stock Exchange such that buyer and seller matching can be done on the exchange.

The Liberty prototype could be used to provide a simplified process to facilitate transfer in the secondary market. For example, a single recommended retail price could be set, one that covers both bids and offers, based on the residual value of the green bond and the government bond yields. For investors who would like to set a bid or offer at this recommended price, there would be a designated trading window facilitated at periodic times, say every Thursday at 2pm HKT as an example. The trading window and set price simplifies the process of trading for all users, removing the need to account for many other market and investment variables, and allowing investors to take a simple opt-in strategy should they desire to sell their holdings or buy more. This mechanism provides a simplified ability to transfer the bond asset as an alternative to the market-driven open venue approach.

From a user perspective, the focus is on providing a seamless interface for retail investors to buy or sell the bonds after the issuance process. Regardless of the back-end market connectivity, investors can place buy or sell orders directly through the platform. More details are provided in the technical overview further on.

1.6 Green Bond Data Feed

The Liberty prototype is integrated with a green data feed from Allinfra that provides asset performance details to green bondholders over the life of the green bond. This increases transparency, provides greater detail on use of proceeds, and allows for greater certainty regarding green impact of the underlying financing. In gathering the climate relevant data from the asset, the Allinfra solution is used to ensure the end user of this data is exposed to as few intermediaries as possible and that the data is easily accessible and verifiable by the user, for instance the asset owner, the lender/bondholder or a third party.
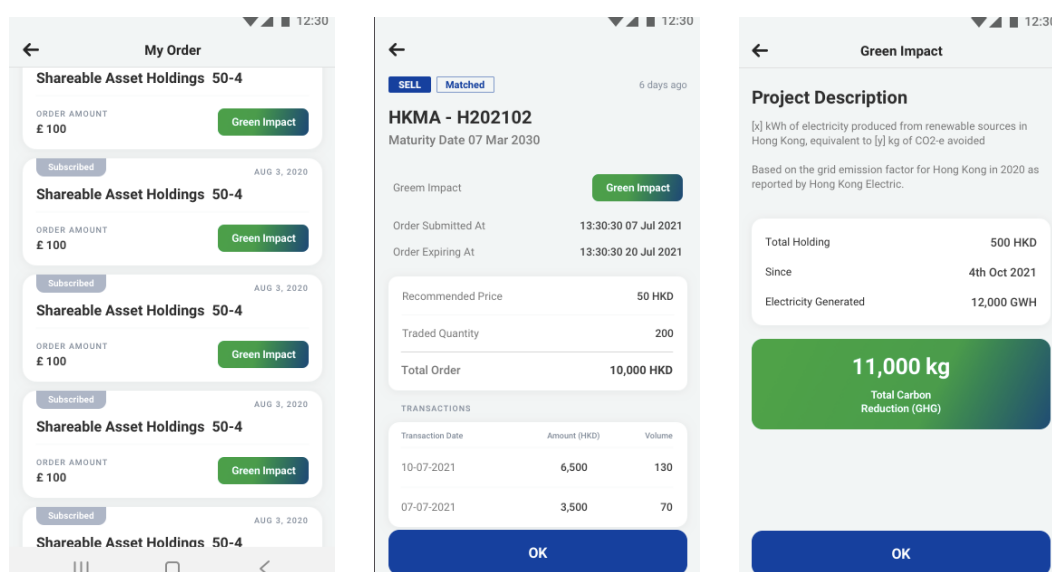

Figure 6: The green impact of subscribed bond holdings.

Through this, the investor can get a reliable sense of the impact their funds are making. For example, where the government invests the proceeds in Hong Kong renewable energy projects, investors can directly see the difference the program is making in their very own community.

1.7 Efficiency Savings

The Liberty prototype has shown the potential to offer several efficiencies for retail bond issuance summarised in the table below:

Shorter Marketing Period, Lower Marketing Cost, and Paperless on-boarding and Subscription Processing	As all information can be distributed instantly across networks, retail investors will receive all the marketing information directly from their Mobile Apps, instead of various online and physical distribution points. This can effectively simplify and shorten the overall marketing timeline. In addition, by keeping all on-boarding and subscription processes on the App, the overall process is greener.
Efficiency Generation through Direct Process	In previous retail bond offerings by the HKSAR Government, there were around 40 banks and local security brokers acting as the placing agents to ensure the broadest distribution and the most extensive penetration. Once the first issuance is done via the Genesis app, issuer will have direct access to investors that have previously bought government green bonds. Furthermore, given this direct access, subsequent issuances could be 3one in smaller "auction style" offerings reducing operational cost and reacting to real-time investor feedback on demand.
Man-hour Savings from Application and Manual Reconciliation of Subscription	Currently, the orderbook of the retail offering subscribed by each placing bank are generated in separate forms consolidated by different teams across a placing bank on a daily basis which is a manual and time-consuming process. Each placing bank will also have their retail staffs handling the physical application at the local branches. In the digital issuance process, the centralised platform can handle investor applications directly and capture investor details and generate the orderbook instantly and automatically.
Transparency	Today, retail government bonds are maintained in electronic book-entry accounts at debt securities clearing and settlement system (Central Moneymarkets Unit, CMU), maintained by the HKMA. In the future, they could "live" on distributed ledgers held across a network of traders where each has a synchronised copy.

Third-Party Savings	While the current process in Hong Kong uses static programme documentation, new offerings in other jurisdictions may require a full documentation process with a comprehensive marketing campaign. In a digital issuance process, investors subscribe to the retail bond via the Mobile App which can support multiple issuances with the same set of documentations. This is economically efficient with the elimination of lengthy and expensive legal documentations reviews.
Potential Future Savings on Placing Agent Fees	In a conventional bond offering, placing institutions may charge investors a handling fee as a percentage of the government retail bond application amount. With transactions including application enquiries performed via the Mobile Apps, this handling fee of 0.15% could be reduced substantially
More Efficient and Liquid Secondary Trading Leading to direct Investor Insights	With bond subscription as low as HKD100, the issuer can access a broader investor base (long tail of retail investors) and investors can easily trade the retail bond on the Mobile Apps resulting in potential improvements in secondary market trading. Furthermore, the issuer will be able to see real-time demand dynamics amongst investors in a comprehensive dashboard, something not attainable today.

Table 2: summary of efficiency improvement in the prototype.

2. Technical Architecture

Tech Stacks
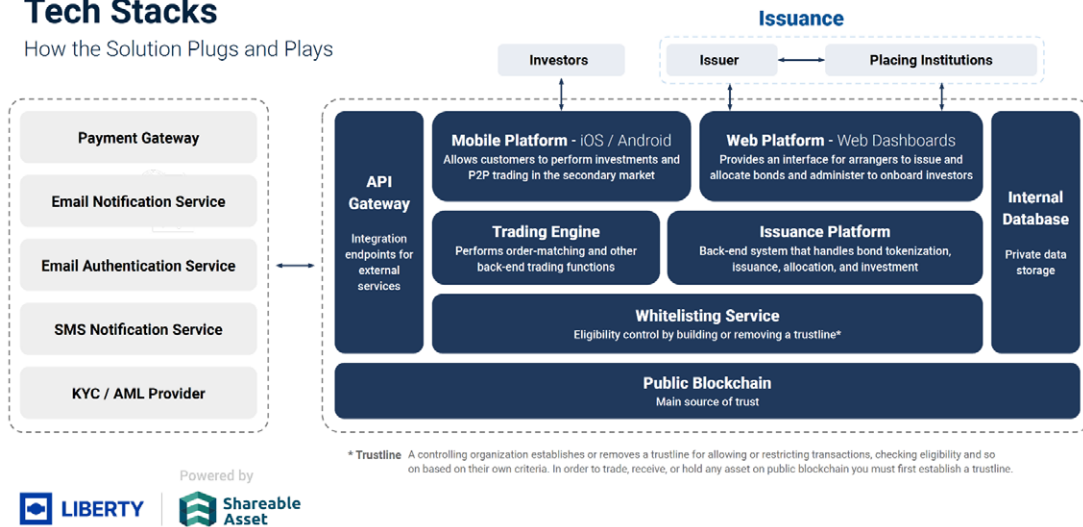How the Solution Plugs and Plays

Figure 7 shows the technology architecture of the Genesis prototype.

As shown in Figure 7, a public blockchain is used as the underlying main source of trust, considering the transparency and data provenance capabilities. An API gateway is the main integration endpoints for external services. A segregated internal database is used to ensure private data is stored separately from public data.

2.1 Interfaces

The Liberty prototype offers two different interfaces for users. The first is a web application, used by issuers and arrangers to conduct management and administrative tasks associated with the asset. The second is a mobile application, designed for usage by retail investors on the platform.

The platform is flexible to support many interface applications, such as integrations with existing legacy desktop systems or existing mobile platform environments, but the existing interfaces emphasise the opportunity in greatly improving the investor's user experience. With a web and mobile friendly approach, the issuer can engage directly with users in a seamless fashion and this improved user experience is a key factor for engaging with the retail investor base.
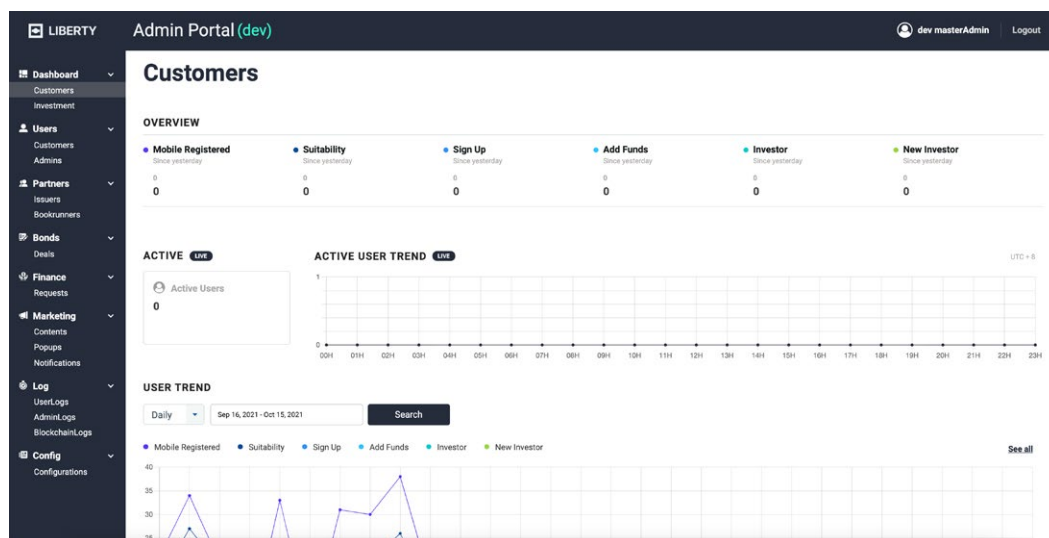
2.2 Web platform

Figure 8: Admin portal view on the web platform summarising the user and bond data.

As can be seen in Figure 8, the web platform in the prototype is designed to handle the administrative and management tasks that are conducted by the asset issuers and bond arrangers. In this case, the HKMA would conduct their management activity directly through the web interface.

In a production scenario or in other markets, existing legacy systems could be integrated as a drop-in replacement for the web platform.
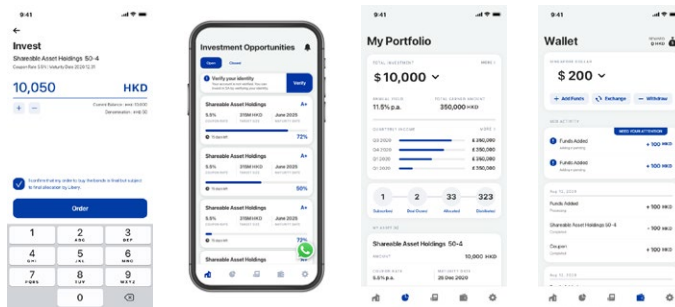
2.3 Mobile Platform

Figure 9: Mobile platform showing the portfolio and wallet view.

The Liberty prototype is designed and built to support forward looking markets and has a full-featured mobile platform for retail users. For users, the mobile application is the main point of access and interaction with the green bond asset and subscription process. From their phone, a user is able to subscribe to the bond listing, take ownership of the bond asset, process associated payments, engage in secondary market trading, and see the resulting green output of the underlying bond purchase. In this way, the Liberty prototype and its mobile application represents a streamlined customer focused experience designed to engage retail investors and green investing.

The mobile application is a combination of a traditional mobile application and a digital asset wallet. Like other digital wallets, it is the software application that provides a customer with a human usable technical interface for interacting with the blockchain and other technology services related to the digital asset.

Tokenization, Cryptographic Keys, and Key Management

Digital assets are registered on a digital registry, in this case, a ledger that runs on the Stellar Network. The ownership of the asset is recorded on the ledger as well. Ownership is expressed using strong cryptography using what is known as public and private keypairs. While there are many considerations and risks when making cryptographic keys usable for end users, they offer the unique capability of providing direct ownership over a digital asset. This means that ownership is always expressed through the presence of the cryptographic key as opposed to ownership being recorded separately. This provides a high degree of interoperability between services. Regardless of the underlying technology, the cryptographic math that validates a key, and therefore proof of ownership of the asset, remains the same across services and devices.

In this way, the digital tokens are akin to holding a stock certificate in a safety deposit box. The deposit box in this case is the digital ledger and the key to the deposit box is held by the user's mobile wallet.

Managing cryptographic keys is a critical challenge and a risk area for solutions like this. Key-pairs in these solutions are a long collection of seemingly random characters and numbers – completely unusable for the average user. However, through the digital wallet interface and in combination with certain techniques, such as multi-signature cryptography, mechanisms can be introduced to help overcome these challenges and present key recovery techniques, backup services, and other solutions.

2.4 Middleware Services

Shareable Asset's Blockchain Middleware

Liberty uses Shareable Asset's eleven blockchain functions to automate the platform through the Stellar Network. These are bond tokenization, bond issuance, bond allocation, bond investment, whitelisting, wallet creation, wallet recovery, wallet migration, settlement, and trading/ownership transfer, and Stable Coin (CS) or CBDC payment.[7]

Through Project Genesis, the Stellar Network is used as the main source of trust for facilitating transactions and changes in ownership structures. The role of Shareable Asset's blockchain facilitator is simply to facilitate transactions and ownership structures for participants without conducting any licensed activities. For this reason, this facilitator model can be universally used as a plug-and-play system in any regulated financial institution and organization complying with the relevant regulatory requirements.
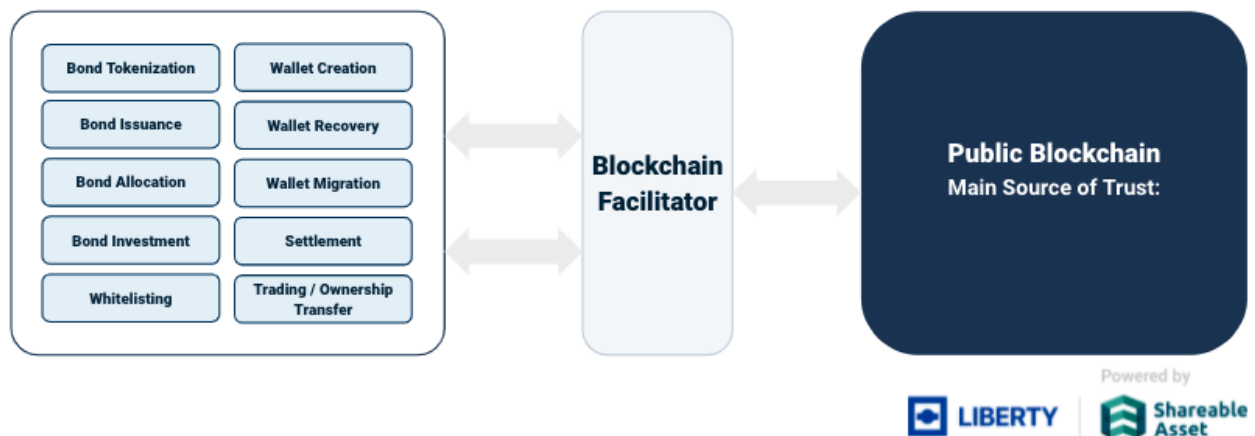

Figure 10: The facilitator model as a plug-and-play system.

The Liberty prototype uses Shareable Asset's blockchain middleware layer to house the business logic that services the platforms core functionality. When the user interacts with the prototype interface, they are making requests to interact with Shareable Asset's blockchain middleware platform, read and store data into off-chain databases, and to interact with third-party or other services as necessary. The middleware services provide the connectivity for each of these components, ensures that all transactions include the correct data and processing logic, and facilitates each transaction with the requisite level of performance, security, and other technical requirements.

Stellar Network interface

One of the key services provided in this layer is the technical interface with the Stellar Network. Access to the network is facilitated through the Stellar Horizon API, which provides an interface and web APIs to facilitate access to the Stellar Network. The Horizon API server and many functions in Stellar that are leveraged by the Liberty prototype are provided in the Stellar Blockchain overview.

Trading Engine

A key functionality explored by the prototype is the inclusion of a secondary market for the trading of government green bonds by retail users.

As previously mentioned, there are two primary mechanisms for enabling such a market within the Liberty prototype: trade facilitated through the HKEX marketplace and trading occurring directly within the Liberty prototype. For both mechanisms, the platform envisages a trading engine to handle basic order routing and a technical service interface.

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[7]   Implementation subject to regulations in respective jurisdictions.

When the secondary market is provided independently, the Liberty prototype provides a direct integration with the built-in Stellar orderbook. Modelled as a decentralised orderbook, in which every node in the network sees an exact copy of all submitted buy and sell offers, the orderbook is a unique function built into the Stellar protocol. The orderbook allows trade offers to be recorded on the ledger, conducts matching of corresponding buy and sell requests, and subsequent execution of these requests within the ledger itself. Through this, the Liberty prototype enables market trading activity in a further streamlined format, but only amongst KYC'ed whitelisted accounts.

For the HKEX marketplace, the Liberty prototype is configured to directly interface with the HKEX Orion Trading Platform (OTP). The trading engine takes user requests via placing institutions, routes them to the exchange, and receives updates as trade requests are matched. In addition, the engine will also receive trade matches resulting from orders that are placed directly within OTP, such as by existing market brokers or by other market participants. While trade matching services are facilitating by OTP, the green bond asset itself is tracked on the Stellar ledger, so final clearing and settlement of the asset for executed trades is conducted in the Liberty prototype. This allows the platform to retain the instant settlement functionality within Stellar, greatly reducing the costs and risks of trading for end users.

Providing such an interface with the HKEX marketplace allows the Liberty prototype to integrate into the Hong Kong ecosystem with minimal disruption to existing market practices. By maintaining settlement within the blockchain ledger, the direct interface between the retail owners and the asset is maintained, allowing benefits such as an atomic swap of the cash and asset. Because settlement occurs immediately and atomically against payment, the need for upfront collateral as margin is reduced and potentially eliminated, ultimately reducing the overall operational burden. The HKEX integration showcases the potential for future market opportunities, such as assets tracked and settled on alternative infrastructure like a blockchain network, to be integrated seamlessly in Hong Kong.

Payment Services

Payment is required to facilitate much of the customer interaction with the green bond asset. Primarily, users must provide payment upon subscription to the bond issuance and for purchases of the bond on the secondary market. To facilitate this, the Liberty platform uses Shareable Asset's CBDC/ CS infrastructure to take the leanest approach possible, using a fiat representation of cash tracked on-chain within the prototype to represent the individual payment obligations of each user.

To facilitate payments, a user will wire money from their preferred bank account to a designated bank account that serves as a trust account for the utility. Upon receipt of funds, the Liberty prototype will recognise the corresponding amount of money in the user's cash wallet, tracked and managed within the platform. Upon purchase of the bonds, either at closing of the initial issuance period or at the execution of a trade on the secondary market, the funds will be exchanged for the assets between the utility accounts in real time. At any time, funds can be withdrawn from the platform by a user in which the corresponding amount of money will be wired into their designated bank account from the utility trust account.

In this way, the Liberty prototype simply tracks a payment obligation in relation to the digital green bond asset. This is different from digital deposits held by banks, which are general purpose payment obligations that are the equivalent of general-purpose cash and is more similar to traditional e-money providers. For the Liberty prototype, this digital representation of fiat, represents a simplified approach to facilitating efficient on-chain payment transactions, without dealing with the complexities of providing full bank-like deposits. Using this same architecture, the prototype can be easily adapted to potential retail CBDC integrations, such as with the e-HKD or in other markets.

Bond lifecycle management

The ongoing activities of the bond, the bond lifecycle, involves various administrative and operational tasks from preparation through closing to the ongoing coupon payments made to the bond owner. These activities are managed within the Liberty prototype which is designed to meet internal compliance and risk management best practices. Every activity performed by the issuer is enforced through a maker-checker process, a standard compliance practice that ensures each activity has a requisite review before going forward. In addition, all actions and their associated user are included in a fully auditable log that serves as a compliance record. With the bond activities fully digitised, the Liberty prototype provides a compliance-friendly platform to allow prospective issuers to easily manage the asset over its lifetime.

2.5 Allinfra Climate Data[8]

The data provided for the green data feed is sourced by Allinfra, a service provider that specialises in integrating climate-related data with infrastructure, finance, and other solutions. Allinfra uses hardware devices and sensors to source the climate-related data, blockchain networks to permanently record and register the data, and a series of other services to provide dashboards visualizing the data saved, marketplaces for the registration and exchange of energy credits and other climate-related assets, as well as the API solutions for integration with other third-party services.

For Project Genesis, this includes a network connected, revenue-grade metering device, able to be used for the monitoring of asset performance, with data fully accessible to the asset owner. The Allinfra platform allows the asset owner to register assets, and other asset specific features, based on static components on a public blockchain (for instance the Ethereum main net). Metered and other non-metered data collected is maintained and referenced across various private services including Hyperledger Besu and other cloud-based storage. Collected data can be accessed and queried in various ways, for example via API, making the underlying data particularly easy to use in dashboards, web and mobile applications and other internal reporting systems.

The key to the Allinfra solution is the proprietary setup that allows the data to be sourced, registered in a verifiable and trusted format, and then utilised further upstream, for example in the Liberty prototype. As green energy goals are integrated into financial assets and other finance solutions, the difficulty of ensuring quality data from the associated projects for both measuring and fraud prevention services is a complex problem. Through collecting, storing, and making available this underlying data in a highly verifiable, auditable way, both the asset owner and third-party users can be confident in that data's provenance and consequently any product reliant on that data. Issues linked to problems such as "greenwashing", which are claims of climate impact made about an asset that are unprovable, and perhaps falsified, are minimised.

Allinfra helps to solve this problem by providing a platform that can ingest many data sources across one or multiple assets, providing the user of the underlying data a rich and reliable data repository, where primary source data can be further supported by other alternative device or non-metered data. The solution could be extended like in the Liberty prototype to prove carbon efficiency gained but can also be integrated in the future with other critical services, such as verification audits, tax disclosures, and other services. In this way, leveraging internet-of-things in combination with blockchain technology, provides a technology foundation necessary to utilise and facilitate trusted green investments.

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[8] See also Section 4.1 of the sister report, Project Genesis Report 1 – A vision for technology-driven green finance.

2.6 Stellar Blockchain

At the core of the Liberty prototype sits the Stellar Network, a blockchain-based, open-source network that facilitates the issuance and exchange of tokenised assets. The Liberty Consortium choose the Stellar Network because of its diverse capabilities, low-fees, and energy and performance efficient consensus mechanism. Since its launch in 2014, it has processed more than 450 million operations by over 4 million individual accounts.[9]

Below is an overview of the Stellar network and how the Liberty prototype makes use of key components within the solution in tokenizing green bonds.

High-level Technology Overview

The Stellar Network is a blockchain-based distributed ledger designed to operate without a central authority. Copies of the ledger are shared between network participants, known as validators, and the Stellar Consensus Protocol keeps the ledger synchronised between validators. The Stellar ledger holds a record of accounts and the balances of assets within those accounts. Validators can submit transactions that make updates to account balances within the ledger, but every validator in the network will process the transaction to ensure it is valid. With built-in features to define who can issue or revoke an asset, to require signatures from network users for certain transactions, and others, functions and services around digital assets can be built leveraging the decentralised Stellar ledger.

Stellar Consensus Protocol

The Stellar Consensus Protocol (SCP) is an algorithm that is responsible for keeping the state of the ledger synchronised between the network participants. Unlike proof-of-work based algorithms, like used in the Bitcoin network, the SCP algorithm is an energy and performance efficient variant. From a performance standpoint, previous work has shown that transactions per second, a common metric of performance within distributed ledger technology solutions, have been able to reach the 1000's using Stellar.[10] For energy efficiency, a research study has shown that an estimate of the electricity required for a single transaction is a factor of 10 less than Bitcoin and similar to that required of Visa.[11]

In simple terms, SCP requires that validators agree to operate between a defined set of other validators. To be compliant with the SCP protocol, the set of validators chosen must include nodes that are sufficiently connected to the rest of the network. As validators are responsible for submitting and receiving transactions from each other, as the updates to the ledger are synchronised between the nodes, a global consensus is reached. This consensus mechanism offers fast settlement finality while maintaining a decentralised model of network participation. The technical details of the algorithm can be found in a peer-reviewed-paper published by the SOSP.[12]

Assets and Anchors

By tracking accounts and account balances using a decentralised ledger, the Stellar network allows many of types of digital assets to be created and, most importantly, to interoperate within a broad global network. Any asset issued on Stellar can be made accessible to users of the network and can be integrated into services and functionality based on other assets in the network. To provide a diverse range of services, Stellar provides critical functionality through the asset transaction APIs in Stellar, such as asset controls and clawback features. This allows asset issuers and service providers to implement critical business functionality, such as compliance or regulations related to financial assets.

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[9] See https://stellar.org/learn/intro-to-stellar.

[10] See https://www.lumenauts.com/blog/how-many-transactions-per-second-can-stellar-process.

[11] See https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=9059429&fileOId=9059655.

[12] See https://www.stellar.org/papers/fast-and-secure-global-payments-with-stellar.

Beyond support for common compliance and regulatory functions, Stellar provides specific requirements and expectations for issuers and service providers that deal with fiat currencies, known as anchors. Any provider in the Stellar network who provides a connection to traditional financial or banking rails, such as domestic RTGS systems or bank-account backed stablecoins, is considered an anchor in Stellar and are expected to adhere to a high quality of service. The SDF encourages licensed and regulated entities to operate as anchors, including adherence to the Stellar ecosystem standards among other expectations.[13]

The Liberty prototype utilises the asset transaction features to ensure that the green bond assets comply with regional and international securities regulations.

Trustlines

One of the features used within Stellar are trustlines, a mechanism that allows controls to be placed on an asset. In Stellar, trustlines must be created between a wallet and an asset before that wallet may hold the asset. This prevents undesired participation or receiving of assets that the user has not requested. In this same way, asset issuers can specify that an assets trustline must be approved by the issuer before the user wallet can hold it.

For the Liberty prototype, this allows the issuer to effectively whitelist only allowed users to be able to access the green bonds. The Liberty prototype utilises the trustline approach in Stellar and integrates it into the user onboarding process to ensure only investors who qualify will be able to participate. In the case of Hong Kong government bonds, that would be holders of a valid Hong Kong ID card.

3. Final Takeaways

3.1 Bond Tokenization

Emerging applications of strong cryptography have allowed for new methods in modelling digital financial assets, chief among these being tokenization. As illustrated by the Liberty prototype in the context of Project Genesis and as further explained in the sister report Project Genesis Report 1 - "A vision for technology-driven green finance", tokenization represents an opportunity to improve the way in which assets are distributed, managed, and custodied between issuers and customers.[14]

Especially in case of direct issuance by the issuer to the retail public through a process such as the one illustrated in the Liberty prototype, placement process flows can be materially simplified, thus reducing complexity and by implication cost. Paired with other technologies such as mobile applications for KYC, more efficient trading and settlement mechanisms, or green data tracking integrated with immutable ledgers for transparency, tokenization offers a powerful value proposition for asset issuers and investors alike.

3.2 Public Networks and Ecosystems

The core back-end infrastructure in the Liberty prototype is the interoperable blockchain infrastructure provided by Shareable Asset. The solution provides a connection to the Stellar Network for the prototype, a public blockchain-based distributed ledger, and supports connection to other distributed ledger networks or other technology as desired.

Traditional databases implemented as a centralised ledger can easily support the bond issuance use case, as they have done in the past and continue to do so. However, these databases are often constrained to the remit of a single organization, limiting their interoperability and appeal in a broader ecosystem. When made broadly available, such as in an open market exchange, centralised solutions are associated with higher costs and typically

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[13] See https://github.com/stellar/stellar-protocol/tree/master/ecosystem and https://www.stellar.org/learn/anchor-basics.

[14] See section 2 of the sister report Project Genesis Report 1 - A vision for technology-driven green finance

are optimised for a segment of assets that benefits most from these costs, such as assets traded in large institutional volumes or with highly complex or risk-prone structures.

For a broadly distributed, government-issued, retail green bond, a decentralised ledger provides the unique capability for the bond to be tracked alongside many other assets, issuers, and use cases at once. From a user perspective, this eventually allows all assets to be consolidated into a single wallet interface versus individual proprietary and private wallets or other access mechanisms.

3.3 On-Chain Payments

As digital assets are managed in a digital ledger representation, it quickly becomes apparent of the need for a digital equivalent of payment. Existing payment infrastructure, such as the Faster Payment System in Hong Kong, while incredibly stable and efficient at serving its customers, introduces a great deal of technical complexity that hampers the overall value proposition for digital asset settlement.

For these reasons, the Liberty prototype implements a basic on-chain cash equivalent that allows the digital green bond to be exchanged directly within the asset ledger.
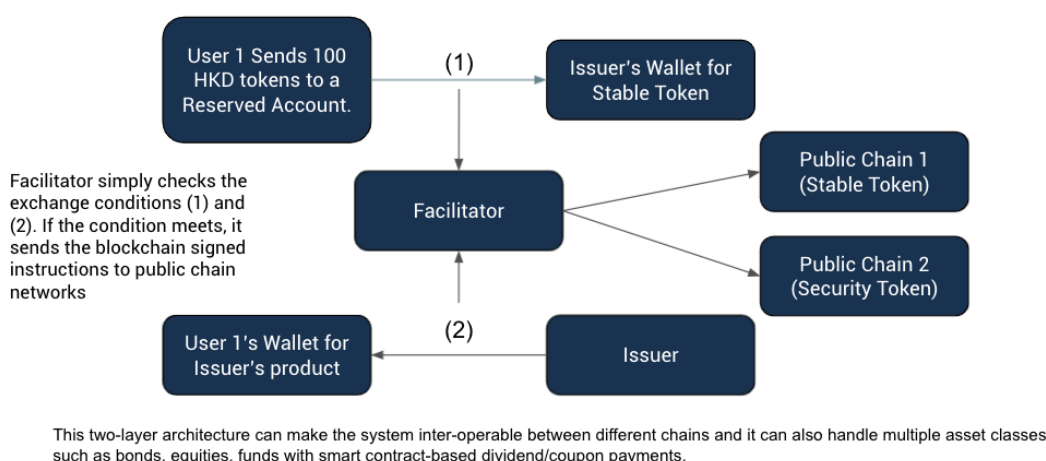

Figure 11: Two-layer payment architecture integrating to CBDCs and stablecoins.

However, continued innovations in FinTech and the Hong Kong ecosystem may provide further opportunities for the need of on-chain cash payments. The issuance of a regulated Hong Kong stablecoin or e-HKD could provide a powerful alternative.

If a generalised form of Hong Kong digital currency was available for portability into the blockchain ledgers, the maximum benefits of digital assets would be enabled, allowing for risk-free delivery-versus-payment settlement in the most efficient way possible.

3.4 Operational and Data Governance

As an end-to-end, standalone bond platform, the Liberty Consortium Prototype is designed to be operated under the direct auspices of the issuer. The recommended model is for an application dedicated to the bond issuance where data around bond holders and exchange activities is made available directly to the issuer.

In addition, while the Liberty Consortium Prototype uses a public blockchain to maximise scalability and increase efficiency, customer identifying information is not placed on chain. While the transaction data is available to all node participants, the identifying information is kept in a secured and private fashion such that only the issuer has knowledge of asset activity. As a result, the most advantageous aspects of a public blockchain are utilised while maintaining complete need-to-know principles across all data streams. Furthermore, with each investor opening a Stellar wallet through the mobile wallet application, control of each investors' assets is directly maintained by each investor. The platform will not have control over assets beyond the legally agreed upon issuance and clawback arrangements.

The Liberty Consortium Prototype can also be run on a private or permissioned blockchain, although but this may increase operational cost and deepen dependency on the viability of that particular closed network through the life of the asset.

Conclusion

The Liberty prototype developed as part of Project Genesis provides valuable insights into the potential future of financial infrastructure. Financial products that are built on forward looking digital platforms are likely to include distributed ledger technology and be implemented in tokenised forms. These products and the underlying ledgers associated within them will be optimised to provide access and interoperability within an ecosystem of partners and service providers. To integrate these systems within a marketplace, whether in permissioned or public form, will require balancing the needs of legacy technology systems with the innovative capabilities offered.

In this way, the Liberty prototype has pursued the full art of the possible. Through Project Genesis, the prototype has successfully shown how Hong Kong may be able to leverage this new technology offering in a real, applicable and compliant way. The insights gleaned through Project Genesis provide useful knowledge for the stakeholders in the financial market.

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