U.S. Municipal Bond Market

Web3, Blockchain and U.S. Public Finance

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- Web3 and blockchain may help usher in an economic revolution based on openness, transparency, and trust that increases productivity and boosts growth. We believe blockchain related technology will progressively enhance the issuance and trading of financial securities not only in the larger sphere of financial services, but also within the U.S. public finance eco-system.
- At a very basic level a blockchain should be thought of as a type of database. A blockchain or blockchains are, in fact, blocks of immutable data that are encrypted and linked to a chain via consensus of its users.
- The traditional processes inherent in primary and secondary market municipal bond activity is ripe for a technological solution. There are a host of third parties that could be streamlined. By utilizing blockchain technology it would be possible to reduce the dependence upon some or many of these third parties. The end effect could be cost savings that would be realized by the public finance entities and tax and ratepayers who are the base of the public finance eco-system.

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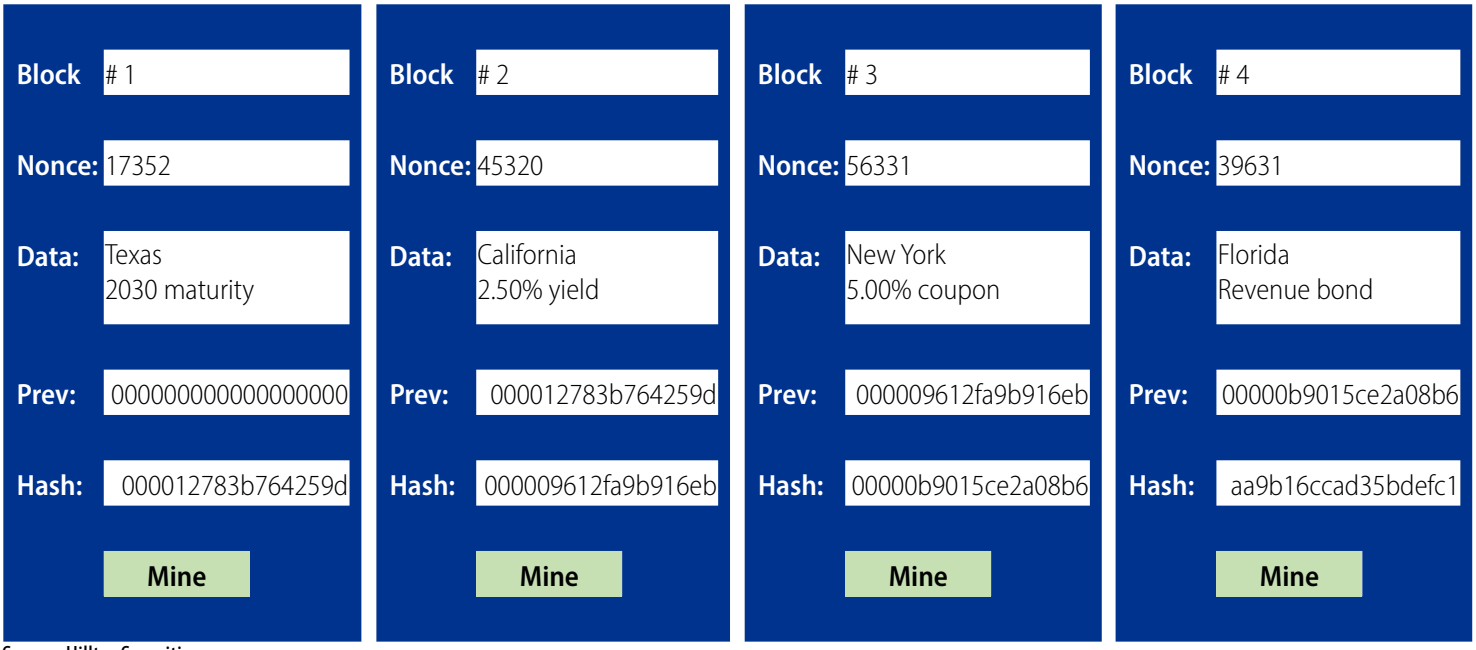
Tech Change Fuels the Next Stage of the WWW, Business

The collapse and bankruptcy of FTX, one of the largest cryptocurrency exchanges, in recent weeks has shined a light on the intersection of technology, regulation and finance. It has brought renewed attention to the disapproval of cryptocurrencies in general and even Bitcoin specifically. At the Spring 2022 Berkshire Hathaway shareholder meeting Berkshire CEO Warren Buffet said he would not pay $25 for all the Bitcoin in the world. J.P. Morgan CEO Jamie Dimon, consistently a cryptocurrency cynic, said during a December interview on CNBC that "Crypto is a complete sideshow," and "Crypto-tokens are like pet rocks."

Blockchain: Blocks of Immutable, Encrypted Data are Added to a Shared Chain by Consensus



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Please see disclosure starting on page 6.

Notwithstanding the FTX related events and cryptocurrency criticism we believe it is important to differentiate between cryptocurrencies and blockchain. Blockchain is the technology cryptocurrencies such as Bitcoin are built upon. However, Bitcoin is only a single application of blockchain technology. To be clear blockchain at this point is only sparingly being used by organizations within business and government broadly. However, even if cryptocurrencies continue to struggle to find their place, blockchain is likely going to be increasingly utilized outside of the crypto world. And blockchain will likely be an important driver of Web3, which conceivably will be the next iteration of the World Wide Web (WWW).

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Web3, along with blockchain may well be the next evolution of the WWW, the internet and help drive connectivity. Web3 and blockchain may even help usher in an economic revolution based on openness, transparency, and trust that increases productivity and then eventually boosts growth. We believe Web3 and blockchain related technologies will increasingly enhance the issuance and trading of financial securities not only in the larger sphere of financial services, but also within the U.S. public finance eco-system.

Three Stages of the World Wide Web

Allow us to operationalize some concepts and review some web history before we dive into the details about how blockchain is being utilized in financial services generally and U.S. public finance specifically. We provide a brief review of Web1 and Web2 to help illustrate what the tech industry is referring to when they speak of what Web3 and what the web experience may very well evolve into in coming years. Web1 is commonly thought of as the first stage of the web experience as it existed in the mid to late 1990s and early 2000s. Computer processing speeds were limited. For all practical purposes it was a one-sided read-only experience. There were blogs and message boards consisting of mostly text early on in Web1. Web sites often counted the number of visitors. Users gained access using services such as AOL. Dial-up modems were more common than broadband access.

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Web2 began to take hold a little less than 10 years ago. This is the next stage in the development of the web and is defined as the transition from the read-only, stagnant web pages we saw in Web1 to more dynamic content. This is the stage when social media became more omnipresent. Processing speeds increased substantially. This increased capacity and new programs allowed higher-resolution pictures and video to be posted and shared. During this phase users began to more actively participate socially and professionally, and they did not just passively consume content. Users began to create and consume their own and other users' content using social media sites such as Facebook, LinkedIn, Twitter, YouTube and others. A distinguishing feature between Web1 and Web2 is that these companies, which grew very large relatively quickly, centralized not only the content but also much of the profit and control of the activity. This dynamic is expected to change in Web3, the next stage of development of the web.

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The third stage of the development of the web, Web3, is currently considered a work in progress. Web3 is expected to replace the centralized nature of what we have experienced in Web2, with decentralized, community and user-made networks. "If the pre-internet/web1 era favored publishers, and the web2 era favored the platforms, the next generation of innovations — collectively known as web3 — is all about tilting the

scales of power and ownership back toward creators and users," wrote investor Li Jin and Katie Parrott in The Web3 Renaissance: A Golden Age for Content. This would return control to the users, or content creators similar to what Bill Gates foresaw back in 1996 in his essay– Content is King. Please also read more about Web3 in What is Web3? by Kevin Roose.

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Blockchain Defined

At a very basic level a blockchain should be thought of as a type of database. That being said, "If databases were birds, then blockchain would be a duck," writes Jerry Cuomo, VP of Blockchain technologies at IBM. This is because while a blockchain can be thought of as a database, or a bird - it has many unique characteristics. A blockchain or blockchains should be thought of as blocks of immutable data that are encrypted and linked to a chain via consensus of its users. Please also see this Blockchain 101 – A Visual Demo by Anders Brownworth of the Federal Reserve Bank of Boston for a more detailed explanation of blockchain.

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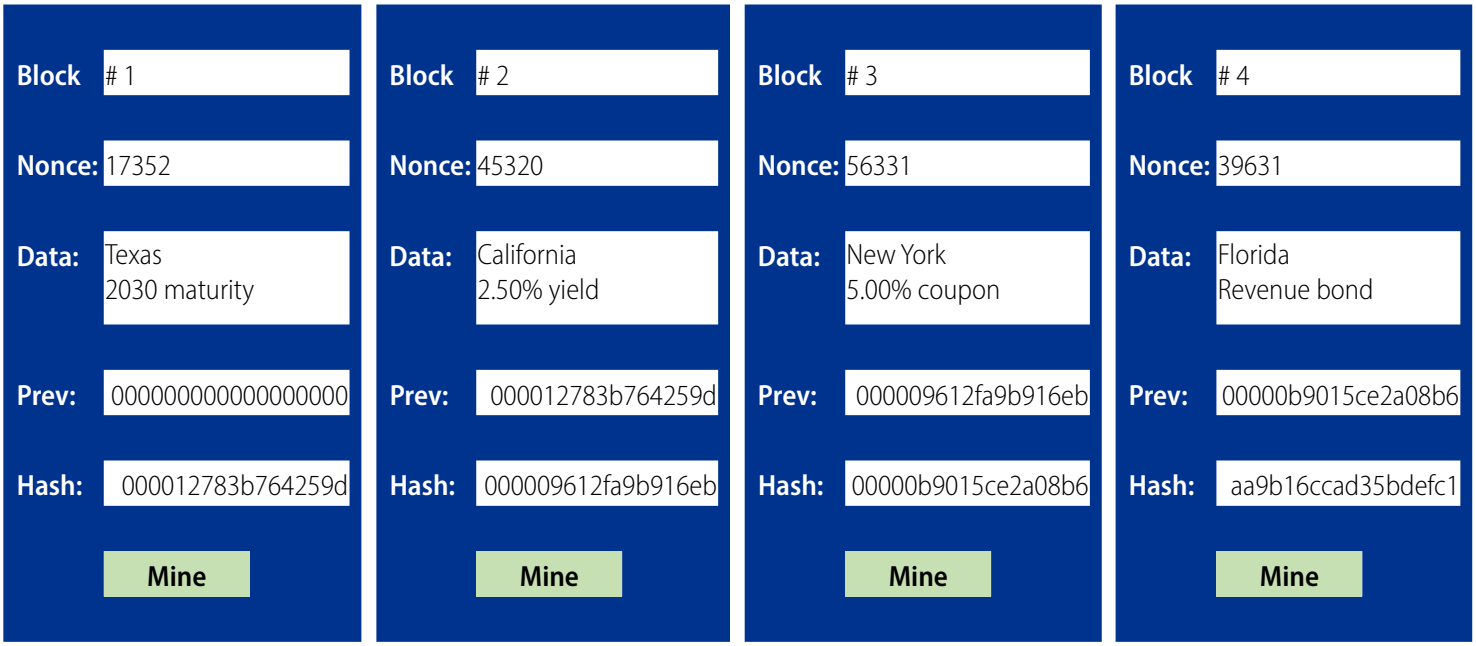

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Brief History of Blockchain

Blockchains were specifically created to avoid third party involvement, regulation, and centralization. In 1991 Stuart Haber and W. Scott Stornetta published "How to time-stamp a digital document" in the January 1991 issue of the Journal of Cryptology. This explored some of the common themes shared now with modern blockchain technology. A framework for a modern blockchain, however, was not proposed until 2008. The paper Bitcoin: a Peer-to-Peer Electronic Cash System was anonymously published by an individual, or a group of individuals known since then as Satoshi Nakamoto. This is blockchain's origin story.

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This groundbreaking proposition pointed out that the internet was reliant on third parties to process electronic payments. Nakamoto suggested, "What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party." Thus a technological solution was proposed, "The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof of work."

Remember, blockchain is essentially an encrypted database, with other important differences.

Nakamoto's paper was the conceptual source of blockchain technology. Initially, blockchain has been the technology that cryptocurrencies are built upon. But there are many, many applications. Remember, blockchain is essentially an encrypted database, with other important differences. A more sophisticated duck is not always needed, especially where a bird will suffice. The duck has been and can be used for financial transactions, supply chain management, real estate, government operations, voting, and other uses. Please see Blockchain: Emerging Technology Offers Benefits for Some Applications but Faces Challenges, by the U.S. Government Accountability Office, March 23, 2022 for more on the uses of blockchain technology.

You may read or hear of permissioned or permissionless blockchains. Conceptually blockchains are meant to be accessible by anyone and everyone. This is the direction Web3 is trying to go. Remember also, transactions made possible with a shared consensus without a third party (regulator, or a central authority) is also one of the key tenants Nakamoto wrote about in 2008. However, there are permissioned blockchains that do limit those who can participate. A permissionless or public blockchain is one that is closer to the original intent of the technology. This is a blockchain that does not rely on a bank, regulator, central authority or third party.

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Blockchain and Wall Street

The integration of blockchain technology into the larger sphere of financial services and Wall Street has largely evolved slowly. Perhaps this is because we often have unrealistic expectations for the integration of new technology. Roy Amara, a scientist, and futurist who famously coined Amara's law stating, "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run." However, blockchain related activity on Wall Street seems to have picked-up in recent years.

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It has been over a decade since Nakamoto's opus, but Wall Street is really just beginning to utilize blockchain technology. There are numerous ways blockchain will be able to enhance the security issuance and the trading process most likely. To date there are some examples of Fintech, and traditional financial services firms slowly evolving toward Web3-like, or blockchain technology. The below examples are not meant to be an exhaustive list, but simply representative of some activity. Arca, founded in 2018, is offering digital shares in its U.S. Treasury fund on blockchain technology. At the end of 2019 a blockchain company called Paxos Trust Co. was allowed to begin to settle stock trades using blockchain technology, enhancing the speed and efficiency of how trades are processed.

In the last two years or so Wall Street's blockchain utilization has evolved. The Wall Street Journal reported (in August of this year in As Crypto Slumps, Goldman Sachs Aims for

a Wall Street Built on Blockchain) that Goldman Sachs developed a digital-asset group of about 70 full-time individuals. Recently Goldman CEO David Solomon indicated that he remained a supporter of blockchain. "As a longtime participant in financial markets, I still see blockchain as a promising technology if allowed to innovate under the right conditions. Under the guidance of a regulated financial institution like ours, blockchain innovations can flourish," the Goldman CEO wrote in a Dec. 6 Wall Street Journal op-ed titled, Blockchain Is Much More Than Crypto. Solomon also reported the firm arranged a trade on a private blockchain.

J.P. Morgan developed its Onyx blockchain platform where it initially conducted trades amongst its broker-dealer and banking groups until its reach was expanded outside the firm in the beginning of 2021. In May 2022 the bank reported a trade on its private blockchain. The New York based bank executed a live DeFi (Decentralized Finance) trade on a public blockchain at the beginning of November 2022. This was an important moment because of the fact that this transaction was on a public (decentralized platform,) and not on a private blockchain.

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Tech-Change and Blockchain in U.S. Public Finance

Modifications are being made in different corners of U.S. public finance and the municipal bond market in response to technological change. Some of the adjustments are regulatory as we have observed with the proposed modification to The Municipal Securities Rulemaking Board's (MSRB) Rule G-14 that could generally require the time required to report a trade to be reduced to one minute. Another tech-related potential regulatory effort could be completed by the end of this calendar year as part of the FY23 National Defense Authorization Act legislation that has passed the House and will be considered by the Senate. Included in the proposed legislation was language similar to the Financial Data Transparency Act of 2022 that would likely require some level of data and document collection by municipal debt issuers in the eXtensible Business Reporting Language (XBRL), or something similar.

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Even more striking is on the business side. A technology firm based in the state of Washington is currently recording municipal digital loans on its blockchain platform. Alphaledger is that technology firm and describes itself as "The Direct Bond Market." In April 2021 Oregon recorded its first digital municipal loan ($1.3 million for Port of Astoria) on the "Alpha Ledger." The municipal advisor was SDAO Advisory Services, OR, bond counsel was Mersereau Shannon, and the lender was Kitsap Bank. One of the co-founders of Alphaledger wrote, "This is a historic event in the democratization of municipal finance," in a post on social media after the loan was completed. Alphaledger also completed a secondary market trade of a digital municipal loan between two banks sometime this year, according to an article in The Bond Buyer.

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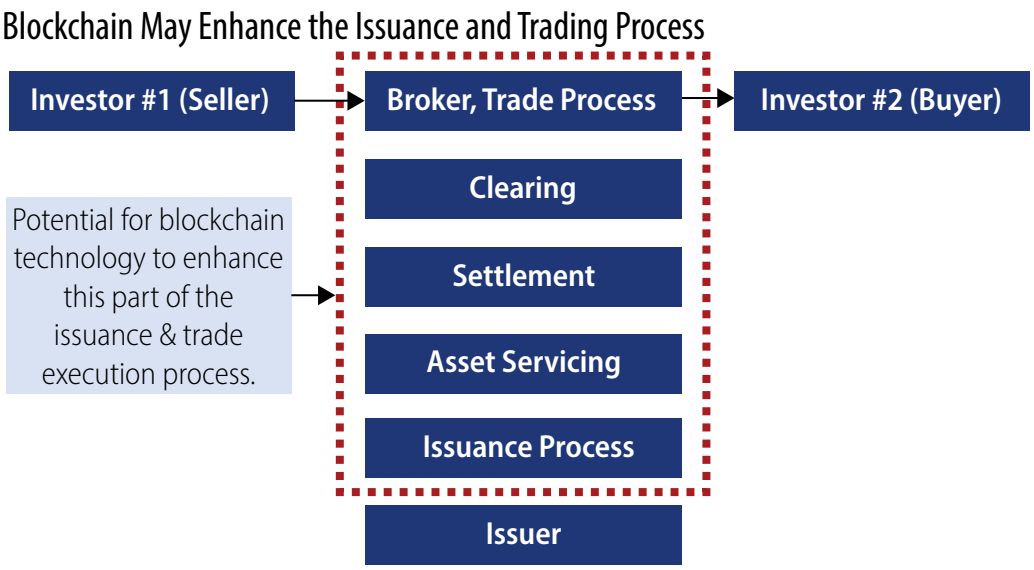
The Future of Blockchain and Municipal Finance

We believe Web3 and blockchain related technologies will increasingly enhance securities issuance and trading not only in the larger sphere of financial services, but also within the U.S. public finance ecosystem. The traditional processes inherent in primary and secondary market municipal bond activity is ripe for a technological solution. This is especially true for smaller issuance and trading activity. There are a host of third parties that could be streamlined.



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The involvement of brokers, underwriters, legal services, clearing services, settlement services, paying agents, trustees, and custodians to name a few could be modernized. By utilizing blockchain technology it would be possible to reduce the dependence upon some or many of these third parties. The end effect could be cost savings that would be realized by the public finance entities and tax and ratepayers who are the base of the public finance eco-system.

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