Correction (first published 07 January 2022) (See disclosures for details)

Cryptocurrency Markets

Crypto-101 and the State of the CryptoMarkets

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The cryptomarkets had a big year in 2021 and we see likelihood for greater acceptance by mainstream investors and companies in 2022. Cryptocurrencies are technology and development continues to blossom driven by the scaling of (new) Layer-1 chains and the introduction and growth of Layer-2. The Ethereum merge is expected mid-2022, which will drive much greater energy efficiently, and we expect will position the 'chain-of-chains' for a significant boost to capacity, transaction speed and usability as we enter 2023. If 2021 was the year of the NFT, we see 2022 as possibly the year of the blockchain bridge (driving greater interoperability of various chains) or the year of financial tokenization. As such, we see the cryptocurrency markets as increasingly relevant to financial services.

- **Bitcoin–Stage-1.** Bitcoin leverages blockchain technology to create decentralized ownership of digital assets, leveraging the transparency of a digital ledger. (We continue to see this innovation as amazing.) Bitcoin as a digital currency has value in that it is highly efficient to own and transact – anywhere in the world in 30 minutes or less. But its nature as a digital asset contains a number of attributes that makes Bitcoin valuable as digital scarcity and as a better store of value often referred to a digital gold.

- **Ethereum–Stage-2.** Ethereum is the evolution of cryptocurrencies to a programmable blockchain, a network that performs computations. This makes Ethereum smart and turns the blockchain into a global computing engine, secured and transparent. This is where the fun really begins because this programmability allows the development of smart contracts, which drives the creation of decentralized apps dApps and more.

- **The Implications.** The applications from crypto have only just begun. Web3.0, greater use of NFTs and tokenization are in the line-of-sight for 2022. As financial analysts, we are most excited about the implications for financial services and see the tokenization and fractionalization as holding particularly large promise as transactions speeds in crypto become more competitive with trad-fi networks. DeFi was a bit of a flop in 2021, but still has strong potential in 2022 and beyond.

- **Coinbase Is Still a Buy.** This primer indicates to us that the use cases for the cryptomarkets will continue to grow and new projects and tokens with more and different use cases will surface. With these projects attached to tokens and Coinbase a leading exchange to buy and sell tokens, we see Coinbase as a leading direct beneficiary of cryptomarket growth.

See page 39 for analyst certification and important disclosures.

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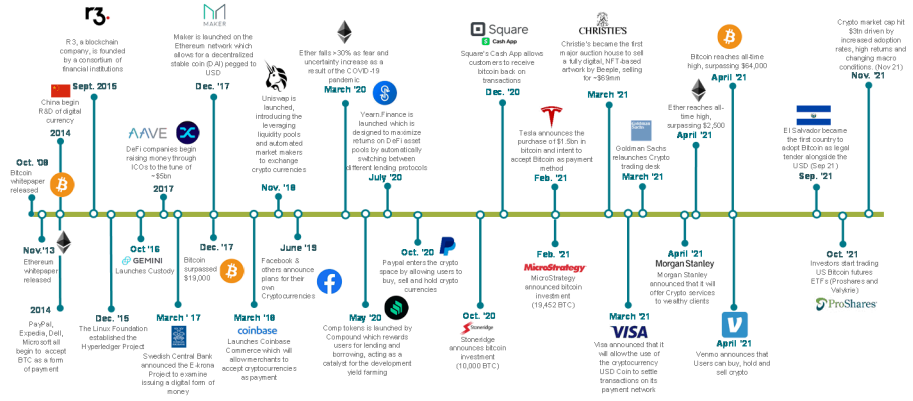
We see 2021 as a seminal year for the cryptocurrency markets as they went from operating at the fringe to being far more mainstream for both investors and corporations. Regulators have also stepped up their engagement in 2H21, but we think the market will need more from Federal US regulators to maintain the innovation momentum.

For investors who want to greater insights into the cryptomarkets and some of its inner workings, we offer a 101-primer with both a discussion on how the cryptomarkets work, as well as the state of the cryptocurrency markets as we see them today. We expect the evolution of the cryptomarkets could accelerate in 2022, particularly for financial services should the promise of greater capacity and transaction speeds be delivered by upgrades to layer-1 chain Ethereum and/or new layer-2 initiatives.

Our takeaway continues to be that taking the time to better understand the cryptoecosystem is worth the effort. We see the likelihood that the cryptoecosystem will be much bigger at the end of the year than it is today, and will have permeated far more of traditional finance three years from now than it has currently. As such we see both the likelihood of more winning business models and investment opportunities, as well as businesses that have the potential to become disintermediated. The leading caveat to our bullish outlook remains regulation and our concern that bending the existing regulatory framework to adapt to the cryptoecosystem could constrain the innovation needed to better develop the cryptocurrency markets here in the US. However, we see politicians as having a far better understanding of the cryptomarkets at year-end 2021 than they did at the beginning, an understanding that we think is a key ingredient to better regulation.

Evolution of the CryptoEcosystem

Figure 1: Timeline of Key CryptoEcosystem Milestones in Recent Years



Source: Onyx by JPMorgan

The cryptoecosystem is still early in its development, being only fourteen years since Satoshi Nakamoto wrote his/her/their whitepaper that jumpstarted the development of Bitcoin and which ultimately gave way to other developments such as Ethereum, smart contracts, tokenization, NFTs, Web3.0 and the Metaverse.

For those that are beginning their journey into the cryptoecosystem, there are some concepts that helped us better understand the value of cryptocurrencies, which helped us set a base off of which to more fully explore the cryptomarkets.

1) Cryptocurrencies are technology. While investors trade tokens like assets, cryptomarkets are technology and the underlying use cases are a big driver of their value. This technology is also the basis for communities that develop around cryptocurrency projects, but in our view the technology comes first and is more important to the initial value creation.

2) The tokens are linked to blockchains. Investors with whom we have spoken are far more willing to ascribe value to blockchains than they are to cryptocurrencies. There is a more easily accepted belief that blockchain technology has value, while the digital tokens are a retail driven pyramid scheme. However, the tokens and the blockchains are linked. Decentralized blockchains need a token with value to incentivize the validation of the blockchain — there needs to be a token and that token needs to have value in both proof-of-stake and proof-of-work. While this token value will fluctuate with supply and demand and thus the tokens can get overvalued, a token with value is nonetheless a necessary component of a decentralized blockchain.

3) Token value is based on the use cases for the blockchain. The value of the token is set by the market, based on supply and demand. Transactions on a blockchain are paid in the native token and thus one needs to purchase the underlying token to transact. For example, ERC-721 tokens (also referred to as NFTs) are bought and sold with Eth (Ether) and gas prices (transaction fees) are also paid in Eth. Acquiring Eth to transact in Ethereum based projects drives up the value of the Ether token.

The Evolution of the CryptoEcosystem

We see the development of the cryptoecosystem happening in three stages: 1) Bitcoin, 2) Ethereum and Smart Contracts, and 3) Tokens and the Metaverse. Each developmental stage builds on the prior and with each stage there are more opportunities to create new engagement and more fulsome communities, and thus develop incremental business and revenue opportunities that didn't exist in the past. While we expect disintermediation, we see the cryptomarkets more about creating new opportunities for engagement and thus more new business opportunities. (NFTs in Art Basil Miami brought out new artists and new buyers, complementing rather than disintermediating the traditional art world, for example.)

We view Bitcoin as being mature in its value proposition, although adoption could still grow quite materially. Ethereum / Smart Contract development and adoption also appear to us to be quite early and depending on the impact of the merge on capacity and transaction costs could propel the protocol to permeate gaming, financial services, real estate and other businesses and asset classes. We see tokenization (non-fungible tokens) and the Metaverse still at their infancy. While NFTs have represented an evolution in the art world and seem poised to infiltrate and alter the gaming industry, we see NFTs and tokenization in their infancy. We still see Web3.0 and the Metaverse as 'in-development.'

With this in mind, we walk through the evolution of the cryptoecosystem in more of a chronological order as we see each stage building on the prior. While many new to

the cryptomarkets have skipped bitcoin and have passed over Ethereum straight to owning NFTs, we see understanding the evolution and building blocks of crypto's origins could be helpful in better understanding the potential for Cryptomarkets and their outlook.

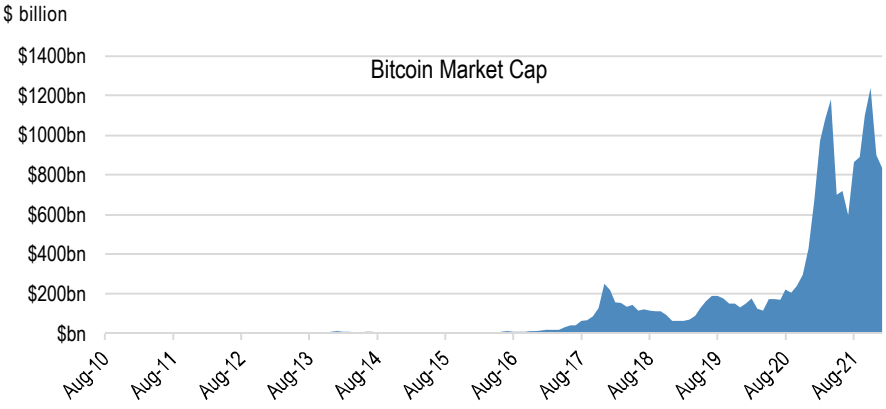
Bitcoin – Stage 1 – A Decentralized Ledger Is the Basis for Digital Value

Bitcoin is a decentralized digital currency, which is to say that it operates free of any central control or oversight by banks or governments. It operates a permissionless and decentralized ledger on which all Bitcoin transactions are recorded. Anyone can join and interact with the Bitcoin blockchain, and Bitcoin users can send 'value' from one account or wallet to another in matter of minutes, without the involvement of a bank or financial institution. Think about transactions as emailing value to anyone or any entity anywhere in the world, 24 hours a day, 7 days a week, 365 days a year. Inherent in the bitcoin software is a hard limit cap of 21 million coins. There will never be more than that in existence and based on the current pace of mining, it will take until 2140 for all the bitcoin to make it into circulation.

The History of Bitcoin Starts with a White Paper with an Unknown Author

Bitcoin was created following the release of a white paper by Satoshi Nakamoto which created an incentive structure that led to the creation of Bitcoin. The digital currency was intended to provide an alternative payment system that would operate free of central control but otherwise be used just like traditional currencies. From here, it has grown to be a well-recognized store of value, with a market capitalization of $871bn (as of Jan-4).

Figure 2: Market Capitalization of Bitcoin Surges in 2020/2021



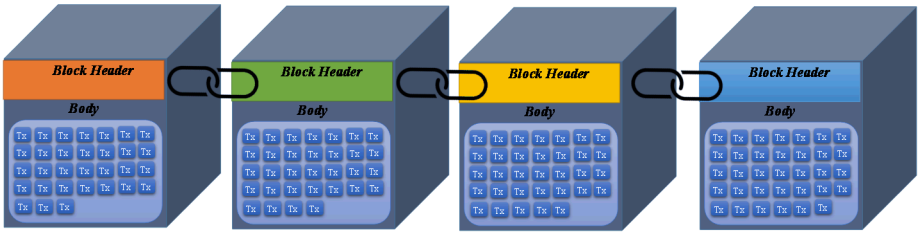
Source: Bloomberg Finance L.P. and J.P. Morgan estimates.

The Workings of Bitcoin

Bitcoin is a digital currency. Transactions are verified by a network of nodes (computers) through cryptography, with transaction details recorded in a public distributed ledger, the blockchain. The blockchain is a linked body of data, made up of units called blocks that contain information about each and every transaction, including date, time, total value, buyer and seller, and a unique identifying code for

each exchange/transaction. Entries are strung together in chronological order, creating a digital chain of blocks. Once a block is added to the blockchain, it becomes accessible to anyone who wishes to view it, acting as a public ledger of cryptocurrency transactions. It is the digital ledger of the transaction history that enables digital ownership, which we see as the genius of the cryptomarkets. Blocks are created approximately every 10 minutes and contain approximately 500 transactions per block. Bitcoin operates at ~7 TPS (transactions per second), very slow in terms of financial services. The official Bitcoin software is maintained as an open-source project by Gavin Andresen, the lead Bitcoin developer at the Bitcoin Foundation, although neither has formal authority over the Bitcoin network.

Figure 3: Digital Representation of the Blockchain



Source: J.P. Morgan.

Walking through a Bitcoin Transaction to Better Understand Cryptomarkets

Bitcoin (BTC) as the first cryptocurrency began trading in 2010, following the 2008 publication of Satoshi's "Bitcoin: A Peer-to-Peer Electronic Cash System," which laid the framework for the blockchain technology underpinning Bitcoin, asset that has appreciated from $1 to $50,000 over the next 12 years.

To better understand bitcoin, we walk through a transaction representing the transfer of a bitcoin from one person to another. By seeing the steps involved in such a transfer, we think it helps in better understanding the cryptoecosystem.

Understanding Public and Private Keys – The Keys to Cryptography

The transfer of bitcoin from one person to another utilizes public and private keys, integral parts of Bitcoin and other cryptocurrencies. These keys work in combination to allow participants to send and receive cryptocurrency without requiring a third party like a bank to verify the transactions. The public and private keys fit together as a key pair, and while one may share the public key in order to receive transactions, the private key enables ownership. If anyone gains access to the private key, they will also have access to any cryptocurrency associated with those keys.

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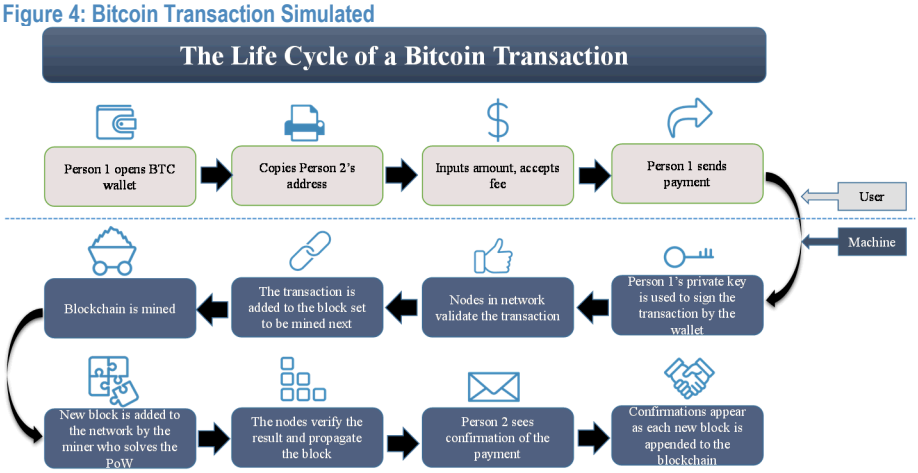
Figure 4: Bitcoin Transaction Simulated



Source: The Times of India and J.P. Morgan.

A transaction that transfers bitcoin from wallet-1 from person-1 to another person-2 in wallet-2 works something like this:

1. Person-1 wants to send one bitcoin to person-2.

2. Person-1 opens his/her wallet-1 and scans person-2's wallet-2 to obtain the wallet-2 public key, which is a series of letters and numbers that a user must share in order to receive funds.

3. Wallet-1 provides the private key to wallet-2, as well as the amount of Bitcoin that is going to be transferred, in this case one bitcoin. In addition, the sender Person-1 will also include a mining fee that is measured in Satoris/vbyte, with the average transaction 250bytes and thus the typical fee $76 or ~15bps.

4. The wallet will communicate the transaction details to a node, which is any computer (a simple PC/laptop) that stores the entire bitcoin blockchain. As of the writing of this note, there are ~12,000 bitcoin nodes that are all interconnected, and communicate with all the other nodes in the network and validate the transaction.

5. Nodes will hold the verified Bitcoin transactions in a mempool (waiting area for bitcoin transactions). Here, miners that have solved the complex cryptographic hash puzzle (discussed in more detail later in the note) will pick up the validated bitcoin transactions. Because a mempool might store 3mbs of transaction data and because each bitcoin block only holds 1mb of data, the miner will sort the transaction in the mempool typically by the mining fee, and will add these higher fee transactions to the block and will collect both the mining fee and the mining reward (6.25 bitcoin). Once the transaction is reported to the block, the transaction is complete.

As seen in the process above, a higher transaction fee will lead to faster execution since it is more profitable for the miner. If the mining fee is below average, the transaction could be sorted to the bottom of the mempool and may wait unconfirmed

in the mempool for hours, days or longer. Until the transaction makes it to the blockchain, it is not complete.

Private keys are the foundation of security for cryptocurrency transactions. Private keys are generated by **pseudorandom number generators (PRNGs)** to generate these random positive integers. Private keys for Bitcoin and Ethereum are 78 digits long with the set of numbers from which a key is selected so massive in size, roughly the same size as the number of visible atoms in the universe, the probabilities of generating two of the same private keys is negligible. As of today, there have been no known hacks that have allowed someone to sign transactions without knowing the private key.

The Process of Mining and Proof of Work

The bitcoin blockchain is validated via the proof-of-work protocol, a consensus mechanism used to confirm that network participants (called miners) calculate valid alphanumeric codes (called hashes), verify Bitcoin transactions and include them in the next block added to the blockchain.

Miners Represent the Security Mechanism for Bitcoin

Mining was introduced as the solution to the double-spend problem. If I have 1 Bitcoin and I send it to someone, and then try sending that same Bitcoin to another person, the network ensures that only one transaction will be accepted. It does this through mining. One of the key features of Bitcoin is its decentralization, operating a digital ledger securely without the involvement of a bank, government or other central authority. But the distributed network needs a mechanism to act as the final arbiter, to ensure that nobody manipulates the blockchain for their own purpose (such as to double spend existing bitcoin as above). Mining is this decentralized security system.

The Digital Ledger Allows for the Ownership of a Digital Asset

To operate a decentralized digital ledger that can be trusted is a challenge, and the blockchain is the best decentralized mechanism yet created and widely accepted to own a digital asset. Because digital assets can be copied exactly, the database/accounting ledger recorded on the blockchain for all to see and verify allows one to show the transaction history of the digital asset and ultimately to prove ownership. Ownership of a digital asset, an asset that can be exactly reproduced in code, is a true innovation of the blockchain and proof of work as a validation of this blockchain is again an incredible innovation.

Proof-of-Work – The Protocol that Validates the Blockchain

Bitcoin uses the proof-of-work protocol to validate the blockchain, the process by which the digital ledger is updated by adding new blocks with all the most recent transactions. This proof-of-work protocol is often described as solving a "cryptographic puzzle." The underlying technology that powers this immutability and security is cryptographic hashing. A cryptographic hash function is a mathematical function that, simply put, takes any input and quickly maps it to a fixed-size string output. Cryptographic hashing is deterministic (any input will always generate the same output), fast, unique (each input with result in a random and unique output such that no two inputs will ever result in the same output), and irreversible (given the output of the hash function, one cannot determine the input).

The algorithm Bitcoin uses to generate the hash is called SHA-256, which always generates hashes as a 256bit number, the equivalent of 64 characters. SHA-256 is an

adaptation of SHA-2, which was created by the NSA in 2001. Bitcoin's proof-of-work algorithm then generates a hash for the block. Think of a hash like a fingerprint that identifies a specific piece of data.

Mining Explained

Mining is the process during which all transactions are broadcast to the network and are usually confirmed within 10-20 minutes. Mining is a distributed consensus system that is used to confirm pending transactions by including them in the blockchain. It enforces a chronological order in the block chain, protects the neutrality of the network, and allows different computers to agree on the state of the system. To be confirmed, transactions must be packed in a block that fit very strict cryptographic rules that will be verified by the network. These rules prevent previous blocks from being modified (altering the records of past transactions for example) because doing so would easily and visibly invalidate all the subsequent blocks. Mining also creates the equivalent of a competitive lottery that prevents certain miners from repeatedly/consecutively adding new blocks to the block chain. In this way, no group or individuals can control what is included in the block chain or replace parts of the block chain to their advantage.

Miners and Rewards

The process of Bitcoin mining involves specially designed computers that aggregate Bitcoin transactions into a block to add to the blockchain. In exchange, the miners 1) collect transaction fees and 2) are paid a reward in the form of Bitcoin by the network. The process starts with Bitcoin miners selecting one megabyte worth of transactions, bundling them as an input into the SHA-256 function, and attempting to find a specific output (solving the cryptographic puzzle) the network accepts. This puzzle is complex and requires significant computational resources to solve. However once solved, the puzzle is both easy to verify as the right solution by the broader network, while also simultaneously validating all current and past transactions in the blockchain. Think of mining as solving a complex 10,000 picture puzzle on the dinner table – it is challenging to put together but once completed it is easy to verify that all the pieces have been put together properly. The first miner to solve the cryptographic puzzle and find this output will publish the block to the network and will receive a reward in the form of transaction fees and the creation of 6.25 new Bitcoin, currently valued at ~$325,000. A new Bitcoin block is added every 10 minutes, which makes the business of mining a big business. We note that roughly every four years, the software running on the blockchain makes it half as profitable to mine bitcoin as it reduces the size of the block rewards.

The Cryptographic Puzzle – Hash This Hash That

A bitcoin block contains a header and a record of all of the new transactions, including buyer, seller, time and date of the transactions. Each block has a unique header that is comprised of six pieces of information: 1) client software version, 2) timestamp of the block, 3) root of the containing transactions' Merkle tree, 4) hash of the prior block, 5) a nonce and 6) the target.

First – let's start with how a Merkle tree chart works.

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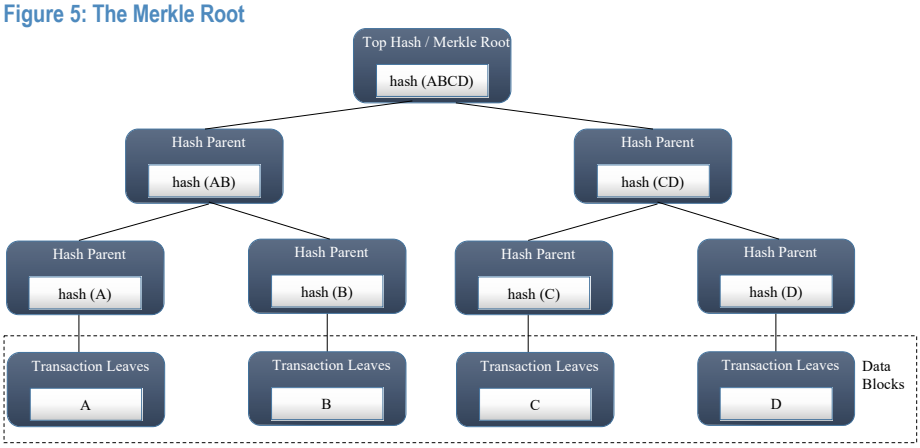
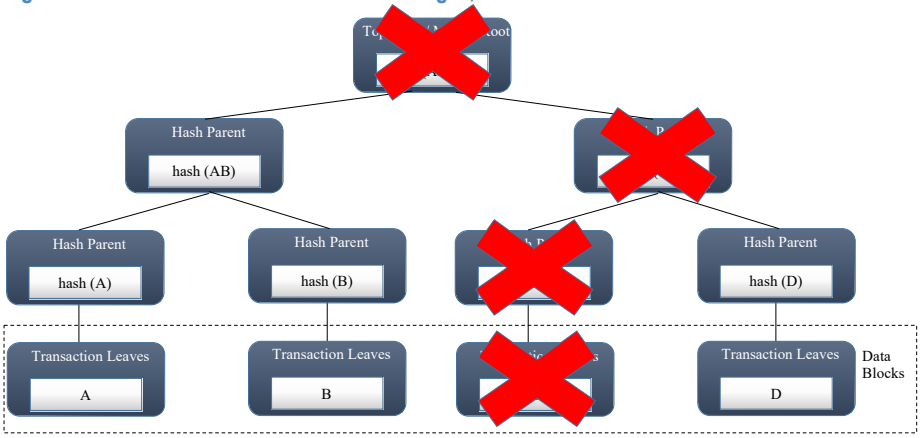
Figure 5: The Merkle Root



Source: J.P. Morgan.

The Merkle root (at the top of Figure 5) acts as the effective summary of all of the transactions in the block. A Merkle tree is simple concept where transaction leaves are hashed together using SHA-256 into parents, and parents are hashed together with those outputs again hashed until a single Merkle root, which becomes the unchangeable summary of all of the transactions in the block. If one of the transactions in the block were changed at a later date, the output in the Merkle root would change all the way up the tree and would be easily recognized by any computer node looking at the root (the top hash in the graphic below.)

Figure 6: When a Leaf in the Merkle Tree Changes, the Parent and Root Is Altered



Source: J.P. Morgan.

Finding the Correct Nonce that Leads to the Correct Block Hash

The core of mining comes from the nonce and the target, which are the basis for the cryptographic puzzle that minors have to solve to create the new block. The miner is trying to find the number (the nonce) that when added to a combination of the known information in the header including the hash of the previous block, the transaction hash of the existing block, and the timestamp of the existing block can be hashed together using SHA-256 to generate the correct 67 digit output (the correct hash signature) for the block to be included on the blockchain.

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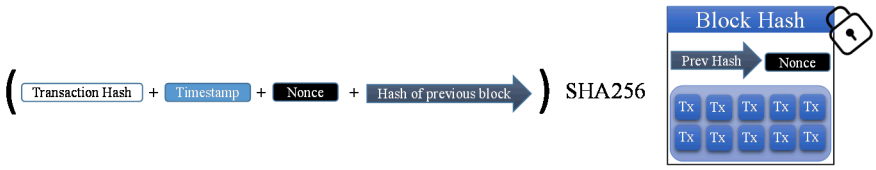
Figure 7: Block Hash

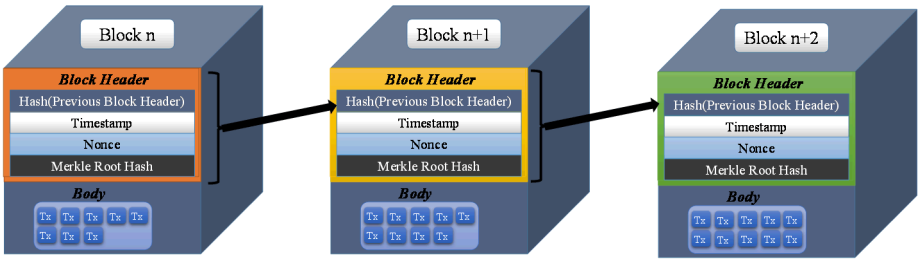


Source: J.P. Morgan.

This is easier said than done. Both the target and the output hash are incredibly large numbers. When converted to base-10, they are 67 digits long. So miners will hash the block header together with their guess at the nonce over and over until they find a nonce that works. For the first block, the genesis block in Bitcoin and the easiest of the cryptographic puzzles, it took nearly 2.1bn computations to find a nonce that resulted in a hash that was acceptable. It has gotten much harder since then.

Below in Figure 8, we show how the block header from one block becomes a component of the block header for the next block. Go back to the Merkle tree — if any old block is altered, the entire chain is changed, which can be easily recognized by the community, which can revert back to the prior chain.

Figure 8: Visual Representation of the Bitcoin Blockchain and the Role of the Block Header



Source: J.P. Morgan.

Once a miner finds a correct nonce, the calculated hash (signature) is added to the block's header. The signature acts as a block lock, preventing further changes to the transactions stored inside the block. The 'winning' miner broadcasts the complete block to other nodes that verify that the nonce results in a correct hash signature. Once 50% of the nodes verify the block, a state of consensus is reached and the block is considered valid and the entire network adds the block to the chain.

The miner who correctly publishes the block is rewarded with new bitcoin, currently 6.25 bitcoin. This takes place in the mining process, as miners are allowed to add an additional output transaction to the block that attributes 6.25bitcoin to themselves. Every four years, the reward for mining bitcoin will fall in half. Sometime in early 2024, the reward will fall from 6.25bitcoin to 3.125 bitcoin. Once all the bitcoin are mined sometime in 2140, miners will work solely for the mining fee.

The Bitcoin network protocol adjusts the algorithm's difficulty every two weeks to maintain a 10 minute average block time. As computational power increases (i.e., the network mining capacity increases), the time to create a block falls, and the target

is made more difficult. On the contrary, if computational power declines (i.e., the network mining capacity declines), as what happened when China banned bitcoin mining last year, the target is made easier.

The Value of Bitcoin

Nothing inherently valuable underpins the bitcoin network, similar to many of the world's fiat currencies since leaving the gold standard. However, we do see value driven by the Bitcoin technology that enables both the concept of digital scarcity and ultimately its merit as a store of value. Such digital scarcity has become more valuable since the outbreak of Covid-19 that contributed to a significant increase in global government debt and drove some to look for alternatives to fiat currencies as global stores of value.

In our opinion, Bitcoin is particularly well designed as a modern store of value, and the strong design has contributed to the increased confidence in and value of Bitcoin. While many are buying cryptocurrencies (chasing in our opinion) because the cryptocurrencies are appreciating and/or are meaningfully outperforming other asset classes, we think the merits of Bitcoin will endure near-term fluctuations in value, both in terms of digital scarcity as well as a good store of value.

Defining a Store of Value – Eight Characteristics

Our research indicates that there are eight characteristics that define a good store of value. We see Bitcoin as being distinguished in six, but disadvantaged in two. Relative to gold, we see Bitcoin is at least or more durable, portable, fungible, visible, scarce, verifiable, and free from censorship. However, Bitcoin falls short of gold in its history as a store of value and we add a ninth as a greater level of price volatility.

- Durable – Bitcoin cannot be destroyed nor does it perish. It will survive as long as the network survives, which given the network is decentralized makes bitcoin very hard to destroy. Wheat, soybeans, corn and other food items have failed in history as stores of value because they are perishable. When comparing gold to bitcoin, both are durable.

- Portable – Bitcoin is particularly easy to store and transport. Large quantities of Bitcoin can be transmitted all over the world nearly instantly and can be stored on a cell phone. Gold is far harder and more expensive to store, transport and insure.

- Fungible – Bitcoin is fungible and is interchangeable with all other Bitcoin. Gold is generally fungible and can be readily seen as better than diamonds, which can have different qualities and shapes that impact value. That said, gold comes in different measures of purity with 24k gold and 14k gold of different values. The edge goes to Bitcoin.

- Divisible – Bitcoin is divisible out to eight decimal places, out to 1/100,000,000, which today is worth $0.0005. Gold is divisible, but not easily accurately.

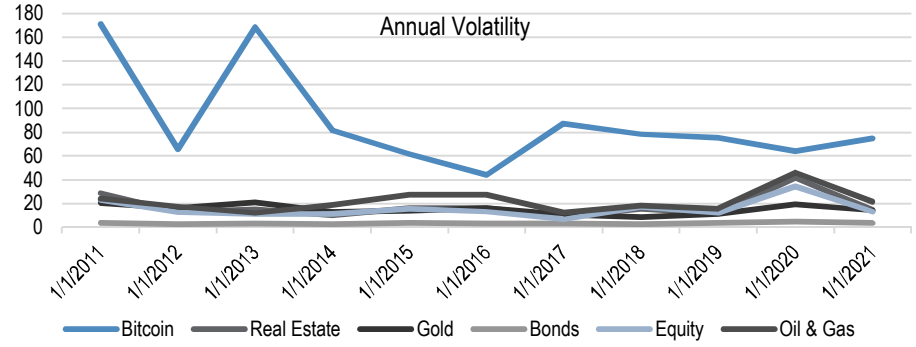
- Scarce – Bitcoin has a finite number of tokens, capped at 21mn, which will be mined by ~2140. Gold is difficult to mine and there is expected to be a finite amount. However, as the price of gold rises, so does the supply.

- Verifiable – Bitcoin is readily verifiable with transactions recorded on the blockchain, which is publicly available for all to view. Gold too is verifiable, but can also be forged and its purity can be diluted, making value more questionable.

- Free from censorship – A censorship resistant asset cannot be stopped or confiscated by any authority, including governments. Users are uninhibited from owning or transferring value at their discretion. No entity (including developers or miners) has any undue influence on a users' Bitcoin. As such, Bitcoin is censorship resistant and because the protocol is decentralized, it is not subject to the demand or constraints of large corporations or governments. Governments do and have restricted both the ownership of gold and the transfer of gold throughout history. The Gold Reserve Act of 1934 prohibited the American people from owning gold, with the exception of jewelry and certain collector's coins.

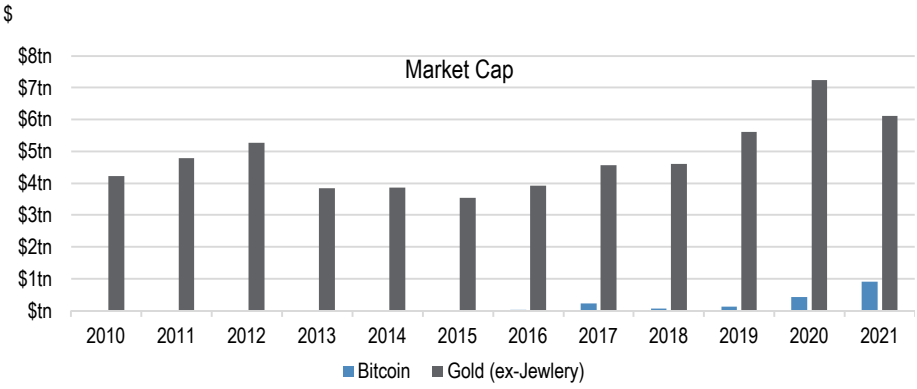
We think Bitcoin falls short of other 'stores-of-value' in two ways. First, Bitcoin has a limited history as a store of value, having only been created in 2009. Gold has been used as a store of value for at least 5,000 years and more likely at least 7,000 years as that is when the first know gold mine was active. Bitcoin is also volatile, with price volatility levels materially higher than other asset classes including gold, the US$, equities and commodities. Because of the evaluated price volatility versus other asset classes, Bitcoin would likely not make a good currency as higher volatility could undermine crypto as a medium of exchange, as a unit of account and as a standard for deferred payments, the other recognized functions of money. But even concerns over higher volatility have been met with Bitcoin support because Bitcoin has been an appreciating asset, volatile for sure, but with significant value appreciation.

Figure 9: Bitcoin Much More Volatile than Traditional Asset Classes



Source: J.P. Morgan estimates, Bloomberg Finance L.P.

Figure 10: BTC Growth Relative to Gold



Source: World Gold Council, CoinMarketCap and J.P. Morgan estimates.

The Transition to Ethereum

While the technology backing bitcoin is significant, we see the use cases for Bitcoin as rather one-dimensional. Bitcoin represents digital scarcity and therefore digital value. But cryptocurrencies made a leap beyond digital value with the development of Ethereum. If Bitcoin is digital value, Ethereum is a digital canvas or software platform that allows developers to create new crypto and traditional applications. Its use cases are far more significant than what we see for Bitcoin.

Ethereum and Smart Contracts – Stage 2 – dApps Take Form

Ethereum was launched in 2014 and it has become a further evolution in the design of and thinking about cryptocurrency networks. It is a more functional and general computation protocol that draws upon concepts from Bitcoin to create application-*based* blockchain transactions, meaning it provides more functions than just account-based sending and receiving. It utilizes blockchain technology not only for maintaining a decentralized payment network but also for storing computer code that can be used to power tamper-proof decentralized financial contracts and applications. So while Bitcoin is characterized as a virtual decentralized currency best recognized as a store of value, Ethereum is a decentralized software platform off of which developers leverage smart contracts to develop decentralized applications and fungible/non-fungible tokens.

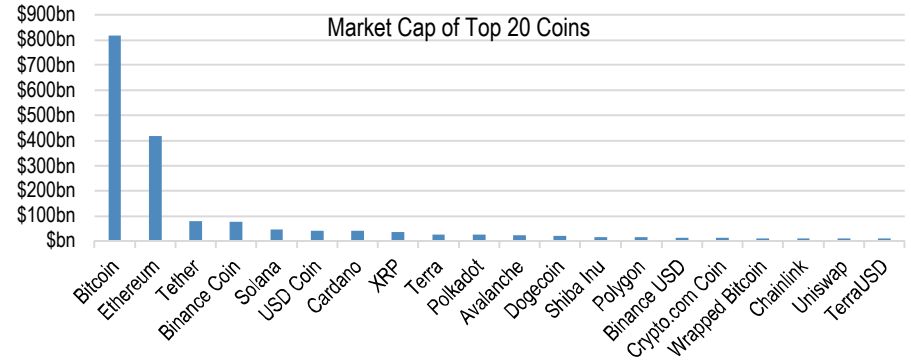
History of Ethereum – Building on the Base Created by Bitcoin

Ethereum was created by Vitalik Buterin in 2014. (Here is a link to his white paper Ethereum white paper published in 2013.) Ethereum is the blockchain and Ether (Eth) is the token, although most refer to Ether as Eth. Vitalik became interested in Bitcoin in 2011, co-founded Bitcoin Magazine in September of that year and remained immersed in all topics Bitcoin for two years. He wrote his Ethereum white paper in Nov 2013 to build Ethereum as a blockchain based platform that could be programmed for many more applications than what Bitcoin could do as a peer-to-peer currency. He built Ethereum to power and build other decentralized applications

like financial tools and social media platforms along with other fungible and non-fungible tokens.

Figure 11: Market Cap of Ethereum vs Other Top 20 Tokens

$ in billions



Source: CoinMarketCap and J.P. Morgan. (1/3/21)

The Workings of Ethereum

While Bitcoin is positioned as a digital currency based on scarcity value, Ethereum is programmable blockchain that is the base of many other fungible and non-fungible tokens. It is often referred to as the 'chain-of-chains' because it is the base-chain or building block for other tokens. Like other cryptocurrencies, Ethereum works on a blockchain network and is therefore a decentralized, distributed public ledger on which transactions are recorded and verified. Like Bitcoin, Ethereum utilizes the proof-of-work protocol to validate its blockchain. But there are some key differences between Bitcoin and Ethereum. Ether block time is faster (Ether transactions are confirmed in seconds while Bitcoin transactions take minutes). Ether uses a different processing algorithm with Bitcoin transactions run off the SHA-256 and Ethereum Etash. While Ethereum currently runs on proof-of-work, it will convert to proof-of-stake mid-2022, a change that we expect could alter the cryptocurrency landscape, as we discuss further below.

A most significant difference between Bitcoin and Ethereum is that Ethereum is programmable and the Ethereum network can perform computations. It is this computational capability that turns what is a store of value and medium of exchange for Bitcoin into a global computing engine and openly verifiable data store in Ethereum. Ethereum as a programmable network allows for self-executing contracts (smart contracts) with agreements programmed right into the Ethereum blockchain.

Ethereum operates under and benefits from three characteristics:

- Large Decentralized Network – Ethereum is the largest cryptocurrency ecosystem and has a significant community committed to the protocol. As such there are significant numbers of smart contracts that have already been written and vetted by blockchain engineers in Solidity (Ethereum's programming language) that can be integrated or expanded into new blockchain solutions. In addition, Ethereum has been tested with billions of dollars of transactions and thus operates with significant credibility. This draws even more programmers and users to the Ethereum network.

- Broad Functionality – Besides being used as a digital currency, Ethereum can also be used to process other types of financial transactions, execute smart contracts and store data for third-party applications. Ethereum's decentralized network promises to let users leave behind third-party intermediaries, like lawyers who write and interpret contracts, banks that are intermediaries in financial transactions or third-party web hosting services.

- Upgrades of the Functionality – A large community of Ethereum developers is looking for ways to improve the network and develop new applications. Ethereum is an evolving blockchain. Recent upgrades (discussed in a separate piece of research on the London Hard Fork) introduced the ability to burn tokens and limit Ethereum mining driven inflation, for example. However, the most radical change is expected mid-2022 when Ethereum is expected to migrate from Proof-of-Work to Proof-of-Stake.

Ethereum – the Chain of Chains Drives New Applications

Because Ethereum is programmable, there are significant applications that have been developed using the Ethereum technology. This begins with smart contracts through to dApps and fungible/non-fungible tokens. We see five general uses for Ethereum.

- **Currency:** Similar to Bitcoin, you can send and receive Eth or pay for goods and services. As such, Eth (Ether) can be a store of value.

- **Smart contracts:** Ethereum allows for the development of smart contracts, permissionless applications that automatically execute when the contract's conditions have been met. It is these smart-contracts that are the basis for the other applications described below.

- **Digital apps, or dApps:** Ethereum powers digital apps that allow users to play games, invest, send money, track an investment portfolio, follow social media and more. Currently, over 440,000 ERC-20 tokens have been developed on Ethereum.

- **Non-fungible tokens:** The majority of NFTs are powered by Ethereum and can allow artists or others to sell art or other items directly to buyers using smart contracts. NFTs are ERC-721, non-fungible tokens. The bonus here is that one can build a royalty structure right into the blockchain, empowering the content creator.

- **Decentralized finance:** By using Ethereum, some people may be able to avoid centralized (government, bank) control over the movement of money or other assets. DeFi is trying to put the central functions of financial services companies on the blockchain, essentially cutting out the bank/broker/exchange as the financial intermediary with the promise of greater speed, lower cost and greater security.

Smart Contracts on Ethereum

Smart contracts are the base on which dApps, NFTs and DeFi are created. A smart contract refers to a piece of computer program that gets executed by a quorum of blockchain nodes and often facilitate the exchange of money, share or property. At their core, smart contracts are executable programs used to automate the execution of an agreement on the blockchain without the need for intermediaries.

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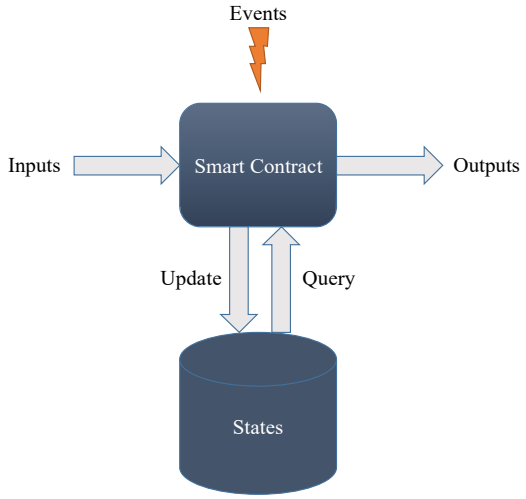
Smart contracts are essentially automated agreements, written in code and baked into the blockchain, making them immutable as well as irreversible. They contain terms and conditions of a mutually agreed contract and can define rules like a regular contract, but that is automatically enforced via the code. Smart contracts are not legally binding the way traditional contracts are. Yet, smart contracts are powerful because they can increase the speed, accuracy, and integrity in payment and performance transactions. Once executed, the smart contract cannot be altered. Yet the ability for Ethereum to support the development of smart contracts is key in the further development of Decentralized Applications including fungible and non-fungible tokens and ultimately decentralized finance, discussed further below.

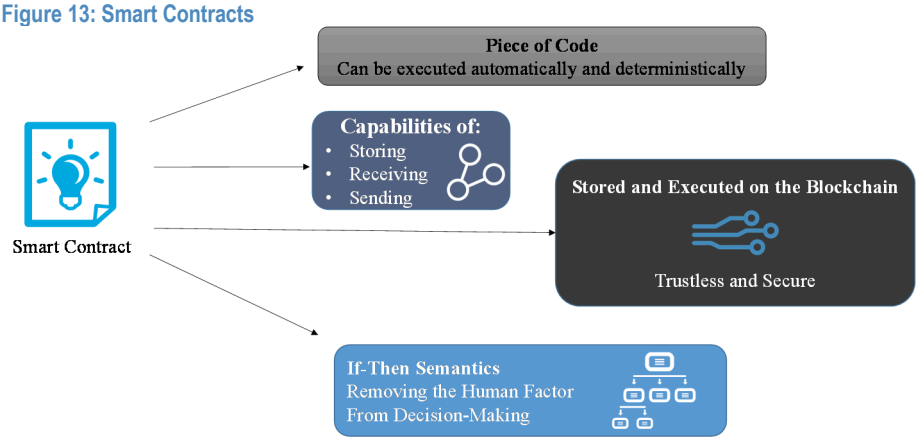
In Figure 12 below, we show that smart contracts are based on program functions, with inputs processed to create outputs. The logic inside smart contracts determine if a transaction is valid, with valid transactions resulting in updated blockchain state, with invalid transactions rejected by the network from being included. The example of an invalid transaction would be the spending of tokens without a sufficient balance.

Figure 12: Smart Contracts



Source: Kaleido.

Figure 13: Smart Contracts



Source: Ethereum.org and J.P. Morgan.

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dApps – Leverage Smart Contracts

Decentralized applications or dApps are similar to traditional software programs, but which run on blockchain networks rather than central servers. The number of dApps has gotten big with more than 3600 dApps spanning different industries such as gaming, financial services and social media. They are growing in relevance and are estimated to be responsible for nearly $200 billion worth (and growing) of user transactions annually.

dApps are decentralized applications, similar to normal apps, but run on peer-to-peer networks like blockchains. As such, dApps are open-source and operate without one entity controlling its data, with records that are publicly available and use a cryptographic token to keep the network secure. dApps are built by combining a user interface front-end and smart contract back-end.

dApp = Front-end + Smart Contract Back-end

In dApps, the front-end can be programmed in any language, but will call a back-end written into the blockchain. In terms of front-end user experience, dApps appear nearly identical to traditional web applications. However on the back-end, dApps function much differently than their conventional counterparts. Instead of employing the HTTP protocol to communicate with the broader network, dApps connect to the blockchain in a decentralized manner rather than routing through centralized servers. We see the power of dApps is their decentralization, which makes them both free from censorship and easier to create. dApps are characterized by:

- **Open source**: The code is public for anyone to look at, copy and audit.
- **Decentralization**: dApps don't have anyone in charge, so no central authority can stop users from doing what they want on the app.
- **No Downtime:** After deploying the smart contract on the blockchain, the network can always serve the needs of clients who want to interact with the smart contract. Furthermore, dApps can also ensure that any malicious actors cannot launch denial-of-service attacks on specific apps. It will continue to function even if parts of the network architecture are non-functional.
- **Censorship Free:** Decentralized apps do not allow control of the data and processes to a single entity. Therefore, it is impossible for any government or entity to block users from submitting transactions or deploying dApps, and even reading data from the blockchain. Without any specific individual or organization controlling a dApp, users have the advantage of complete freedom with dApps.
- **Private**: You would find that a major share of decentralized applications does not demand the real identity of users. Rather than going through a complicated and lengthy signup process, users could access dApps with their Ethereum login credentials and a digital wallet.
- **Data Integrity:** With the power of cryptography, decentralized applications ensure the secure storage of data on relevant blockchain networks. Furthermore, the accessibility of public blockchain for verifying transactions also provides the assurance of reliability in data records.

Most Dapps Are Built on Ethereum

The Ethereum network currently dominates dApp development, hosting almost 3,000 dApps according to State of the dApps. Ethereum makes dApp development easier by offering a development interface that reduces programming time and helps projects quickly launch. In addition, the Ethereum developer community has grown significantly since the platform's launch with a network that shares code and ideas. Ethereum also retains formidable network effects from its global coalition of technologists who remain committed to maintaining the network and actively developing user resources that drive adoption. The ability to monetize DApp projects incentivizes others to partake in the Ethereum ecosystem.

Ethereum also uses a network-native language Solidity for coding smart contracts. But the network architecture eliminates the need to develop an entirely new blockchain for every dApp. Once a smart contract is created, it is uploaded to the Ethereum Virtual Machine (EVM), which is a runtime compiler that executes the smart contract code. EVM is operated in what is called a 'sandbox' environment, which is isolated from the main network to create an optimal testing environment. Once the code is on the EVM, everyone part of the Ethereum network has a copy of the contract. Once the smart contract is tested and verified, it is uploaded to the Ethereum Mainnet.

Developers can work with the ready-made Ethereum system to fast-track onboarding and get their applications up and running sooner than other alternatives. By combining application templates and the EVM, the overall Ethereum development kit allows companies to focus on refining their applications and developing on top of open-source code among a global, mission-based developer community.

dApps and Tokenization

We see tokenization as one of the major foundations of Ethereum. Tokenization is a feature used to define smart contracts and is a core element in dApps. But when we refer to tokens, there are two standards that have emerged on Ethereum – ERC-20 and ERC-721. (The ERC stands for Ethereum Request for Comment, which is the system that allows for comments on the standardization of Ethereum tokens and features a standard set of rules for creating tokens.) As we reflect back, we see a number of references to 2021 as the year of the NFT. To us, it is just the beginning of tokenization.

ERC-20 vs. ERC-721 Tokens

There are two main token standards for Ethereum tokens. At their most basic level, ERC-20 tokens are fungible tokens and are used for all smart contracts on the Ethereum blockchain. Examples include BinanceCoin (BNB), the fourth largest token by market cap at $78bn, Stablecoins Tether and USDC, which have a combined market cap of $121bn. ERC-721 are non-fungible tokens (NFTs), which are a type of unique digital certificate, registered on a blockchain that can be used to record ownership of any asset, best known for digital collectibles. While ERC-20 tokens represent a single asset and are interchangeable, ERC-721 tokens are indivisible and represent a collection of assets. Examples here including CryptoKitties, Etheremons, Crypto Bots, and Blockchain Cuties.

Figure 14: ERC-20 vs. ERC-721

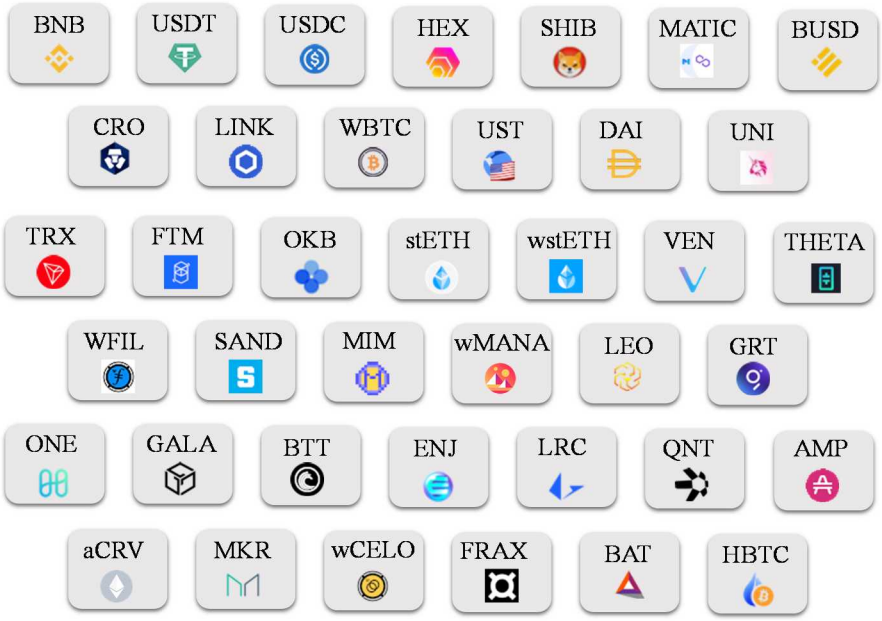
Source: 101 Blockchain and J.P. Morgan.

ERC-20 – The Fungible Tokens

ERC-20 was created by Fabian Vogelsteller in 2015 and is the standard for creating fungible tokens that are compatible with the broader Ethereum network. ERC-20 tokens are built on the Ethereum blockchain and adhere to a set of standards that allow the tokens to work with all other Ethereum smart contracts, enabling the exchange of one ERC-20 token for another and allowing the easy integration with other smart contracts, wallets, or marketplaces. ERC-20 smart contracts use ERC-20 tokens to make payments when their protocol calls for it. Any smart contract that involves payments will therefore pay the user in the form of an ERC-20 token.

Many dApps built on Ethereum have their own cryptocurrencies or "tokens." As of August, there were over 440,000 ERC-20 tokens on Ethereum's main network across more than 900 projects. ERC-20 tokens are typically sold via a variety of different offerings as a way to raise early-stage capital for the underlying project. Many of the projects raised money in the initial coin offering boom of 2017.

Figure 15: The Biggest ERC-20 Tokens



Source: CoinMarketCap and J.P. Morgan.

In order to interact with the dApps, users need to purchase the dApp's native token. One purchases an Ethereum-based NFT using the ETH token, for example. Generally speaking, a token represents something specific in a given ecosystem. This could be economic value, a dividend, a stake, a voting right, really anything. It's important to understand that a token is not limited to one particular role; it can fulfill various different of roles in its native ecosystem. That said, the most common use for tokens is to transact. There are three types of blockchain-based tokens that we will discuss:

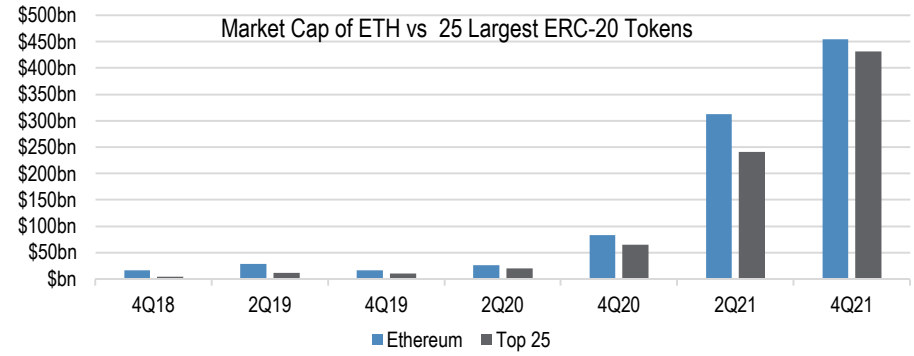
- **Usage tokens:** A token that is required to use a service. These are the tokens that function like a currency in their respective dApps. This is generally the most simple and straightforward application of a token. These tokens have monetary value, but don't come with any sort of rights or privilege within the particular network.

- **Work tokens:** A token that gives users the right to contribute work to a DAO and earn in exchange for their work. In this model, the user (or service provider) stakes the native token of the network to earn the right to perform work for the network. Given a fixed supply of tokens, service providers will rationally pay more per token for the right to earn part of a growing cash flow stream. The important thing to understand at this stage is that work tokens grant access to the network and provide cash flow potential conditional on the delivery of work with the token.

- **Security tokens:** An external, tradable asset that is a representation of value in a system. Security tokens, also known as tokenized securities or investment tokens, are financial securities compliant with SEC regulations. What makes security tokens so neat (and potentially revolutionary) is that the rights are written into a smart contract and the tokens are traded on a blockchain-powered exchange – 24/7/365 with near instant settlement.

Figure 16: ERC-20 Tokens Growing in Capitalization Is a Growing Part of Ethereum

$ in billions



Source: CoinMarketCap and J.P. Morgan estimates.

Current Cases for ERC-20 Tokens:

- **Crowdfunding:** Sometimes Ethereum app builders decide to raise money for their projects via crowdfunding. In return, investors receive newly minted tokens prior to the official launch at wholesale prices.
- **Voting rights:** Tokens can be used for voting on project decisions. In this instance, the more tokens users have, the more influence they have over each election.
- **Represent physical objects:** A token can represent ownership of assets, such as gold.
- **New features:** Sometimes builders need a token for paying for the functionality of their projects, but the native token on Ethereum, Eth, is not enough for them. So, they create a new token with the functionality they need.

ERC-721 Tokens -- NFTs

The ERC-721 Token standard enables Non-Fungible Tokens (NFTs) on the Ethereum blockchain. Just like the ERC-20 token standard helps in creating fungible tokens, the ERC-721 focuses on non-fungible assets. ERC-721 tokens help bring the concept of uniqueness to the blockchain, ensuring that distinctive details about an asset can be immortalized. NFTs can be used to provide digital representation of a one-of-a-kind artwork, with ownership that is easily proved through blockchain records and can limit things like counterfeiting.

The Ethereum Foundation describes the workings of an NFT like this. An NFT has one owner at a time, which is managed through the uniqueID and metadata that no other token can replicate. NFTs are minted through smart contracts that assign ownership and manage the transferability. When an NFT is created, the creator executes code stored in smart contracts that conform to a certain standard, such as ERC-721, and this information is added to the blockchain where the NFT is being managed. The minting process, from a high level, has the following steps that it goes through:

- Creating a new block

- Validating information
- Recording information into the blockchain

NFTs have different properties than ERC-20 tokens, which expand the use cases from what one can do with these tokens. While we discuss the implications later in the note, some key properties are as follows.

1. Each NFT has a unique identifier that is directly linked to one Ethereum address.
2. NTFs are not directly interchangeable with other tokens 1:1. For example 1 ETH is exactly the same as another ETH. This isn't the case with NFTs.
3. Each token has an owner and this information is easily verifiable. Here, the token proves that the copy of the digital file is the original and the private key is proof-of-ownership of the original. The content creator's public key serves as a certificate of authenticity for that particular NFT.
4. They live on Ethereum and can be bought and sold on any Ethereum-based NFT market.

Current use cases for NFTs are in digital entertainment including art and music, but are increasingly being used as assets in gaming. We expect NFTs will become a key part of DeFi with the tokenization of particular value for illiquid assets. Below we show a compare and contrast between the current internet and an NFT internet, which is presented by the Ethereum Organization.

Table 1: The NFT Internet vs. the Internet Today – A Compare and Contrast

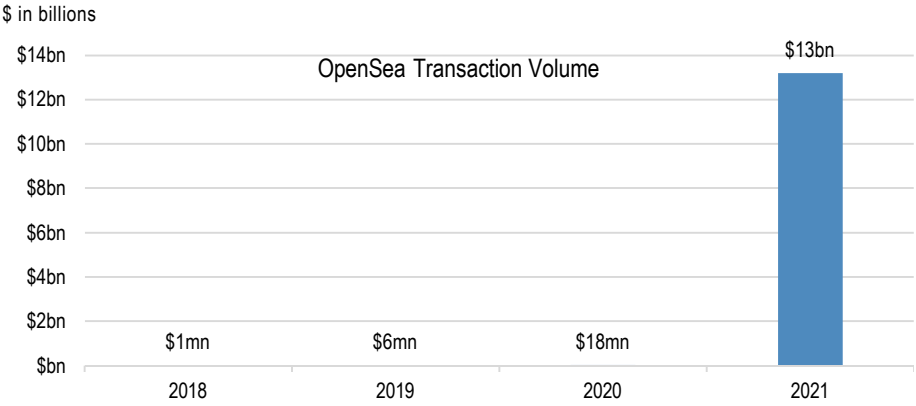
An NFT Internet	The Internet Today
NFTs are digitally unique, no two NFTs are the same.	A copy of a file, like an .mp3 or .jpg is the same as the original.
Every NFT must have an owner and this is of public record and easy for anyone to verify.	Ownership records of digital items are stored on servers controlled by institutions - you must take their word for it.
NFTs are compatible with anything built using Ethereum. An NFT Ticker for an event can be traded on every Ethereum marketplace, for an entirely different NFT. You could trade a piece of art for a ticket!	Companies with digital items build their own infrastructure. For example an app that issues digital tickets for events would have to build their own ticket exchange.
Content creators can sell their work anywhere and can access a global market.	Creators rely on the infrastructure and distribution of the platforms they use. These are often subject to terms of use and geographical restrictions.
Creators can retain ownership rights over their own work, and claim resale royalties directly.	Platforms, such as music streaming services, retain the majority of profits from sales.
Items can be used in surprising ways. For example, you can use digital artwork as collateral in a decentralized loan.	

Source: Ethereum Foundation

NFTs Have Grown -- Materially

NFTs have grown materially, to such an extent in 2021 that some in the crypto markets refer to 2021 as the year of the NFT. One way to conceptualize the growth is to look at transaction data. Below we show a chart on the growth in transaction volume on OpenSea, the leading NFT marketplace, as an indicator on the growth of the NFT market.

Figure 17: OpenSea NFT Transaction Volumes Has Grown Materially



Source: OpenSea and J.P. Morgan.

The Downside of Ethereum – Getting More Congested and Expensive

Ethereum's success and popularity have created a number of problems for the network. With increasing numbers of fungible and non-fungible tokens running on Ethereum, network congestion have driven gas prices / transaction fees to rise materially for Ethereum based transactions, making it expensive to transact on the network. It can regularly cost $40-$50 per transaction, making the purchase of simple NFTs or the movement of Ethereum from one wallet to another an expensive proposition. Ethereum is also energy intensive and doesn't communicate well with other blockchains. It's a bit like having a cellphone that can only text users on the same network. Ultimately Ethereum's problem has been its limited ability to scale with the increasing popularity of the network.

Lack of Scalability

One of the core problems with the Ethereum platform has been scalability. As more and more decentralized apps use the platform, and transactions increase exponentially, so do the gas fees. Simply put, if there are too many users on the blockchain, it gets more expensive to buy and sell things.

Increase Cost to Transact on Ethereum – Rising Transaction Costs

Ethereum's growing popularity has led to higher transaction costs. Ethereum transaction fees, also known as "gas," have been rising for much of 2021. When we tried to buy NFTs for the kids for presents this holiday season, we ended up paying more in gas fees than in NFT prices. While in Bitcoin the network itself rewards transaction verifiers, Ethereum requires those participating in the transaction to cover the fee. In Ethereum's current state, only those with larger holdings can make use of the benefits of its ecosystem. Swapping cryptocurrencies on Uniswap, a decentralized exchange and liquidity provider on Ethereum's network, costs nearly $150 earlier this year, making trading small amounts of money impractical.

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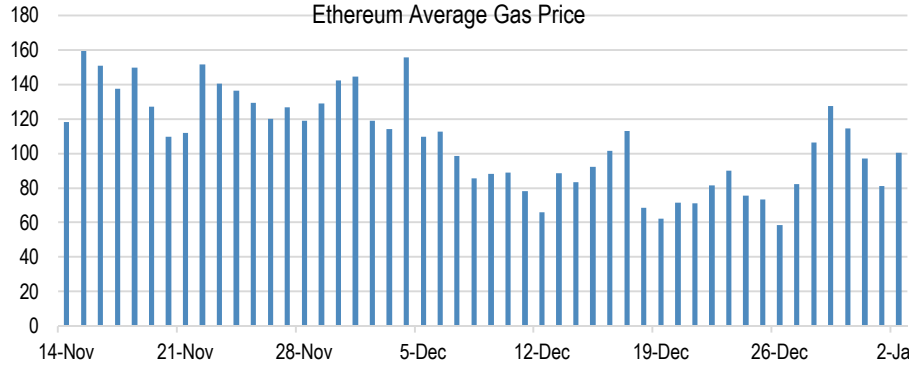
A Word on Ethereum Gas Fees

Transaction costs on Ethereum are referred to as 'gas' fees, which are paid in ETH. Gas fees are paid when information is added to the Ethereum network, for example when an ETH token is purchased or sold or when an NFT is created on the Ethereum blockchain. Processing transactions on Ethereum network requires computational power and gas is the fee paid to miners for providing that computational power. Gas fees are measured in Gwei, the smallest base unit of ETH – 1/1,000,000,000 of an ETH. Gas fees were created to both compensate and incentivize the miners to undertake the computational costs of using the Ethereum Virtual Machine (EVM) to execute the transaction. But Gas fees also help keep the Ethereum network secure. Attaching cost to every transaction prevents spamming or accidental infinity loops that could unintentionally or maliciously consume the resources of Ethereum and prevent new transactions from being recorded. More complex transactions require more gas to execute, with transactions involving smart contracts costing more than transfers of ETH between two wallets. Average daily gas prices in Dec 2021 have ranged from a low of $62 on Dec 19 to a high of $156 on Dec 4. Because transaction fees need to be paid in Eth, participants on the Ethereum blockchain need to acquire ETH, which results in value for ETH.

Figure 18: Eth Gas Prices Remains High

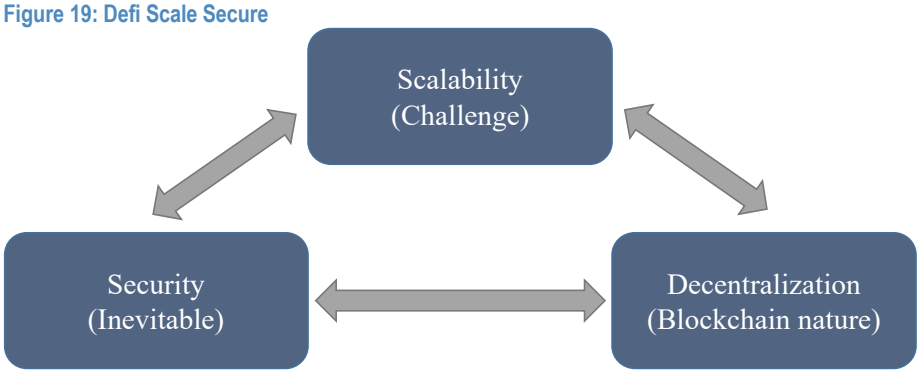


Source: ycharts.com

Ethereum Suffers from Slower Transaction Speeds

Ethereum runs at 15 transactions per second. This is faster than Bitcoin's 7tps, but is substantially slower than the MasterCard's network, for example that can process 5,000tps. Ethereum transaction speeds are being hurt by a number of factors including greater data store needs given the increased usage of Ethereum and the need to drive consensus with an increasing number of nodes. The Blockchain trilemma reflects the tradeoffs between scalability, security and speed. In the case of Ethereum, the network prioritizes security over scalability.

Figure 19: Defi Scale Secure



Source: J.P. Morgan.

Inflation – The Issue of More Eth Issued as Part of the Mining Process

There is a natural rate of inflation for Ethereum. While the number of bitcoin tokens is capped at 21mn, the number of Ethereum tokens had been rising at an ~4.7% annual inflation rate (2020 inflation rate), driven by mining rewards at 2 ETH/block. However, with the release of EIP-1559 (explained further below), ETH is now being burned as part of every Ethereum transaction and thus the rate of inflation has fallen to 1.7%. Following the Ethereum merge, there is the potential for ETH deflation.

Solutions for Ethereum's Challenges–The Cryptoecosystem Addresses Ethereum Network Issues, One Way or Another

The problems with Ethereum are frustrating its user base, enough to drive them to action. Alternatives have been developed that include both the creation of new blockchains that attempt to address Ethereum's speed and congestion issues. We have also seen Layer-2 solutions (both Ethereum Layer-2 and other chain Layer-2) including sidechains and other rollups that are bridges to address Ethereum's scalability issues. Finally, Ethereum is a blockchain that continues to evolve and the Ethereum merge scheduled for mid-2022 is expected to address scalability issues.

Launch of Other Programmable Blockchains – Other Layer-1 Solutions

The cryptocurrency market is building on the innovations developed with Ethereum by launching other blockchains that address some of Ethereum's shortcomings. These are underlying main blockchains, also known as Layer-1 chains. Ethereum has the first-mover advantage over all other altcoins and smart chain platforms and is recognized as the biggest decentralized marketplace for financial apps, services, and games. However, crypto markets continue to evolve and so-called 'Ethereum killers' are gaining popularity based on their improvements made versus Ethereum. Solana is much faster than Ethereum. Cardano is more scalable. Polkadot is more interoperable. These advantages could allow these other chains to chip away at Ethereum's dominance and market value as they facilitate the development of new projects levering Ethereum limitations.

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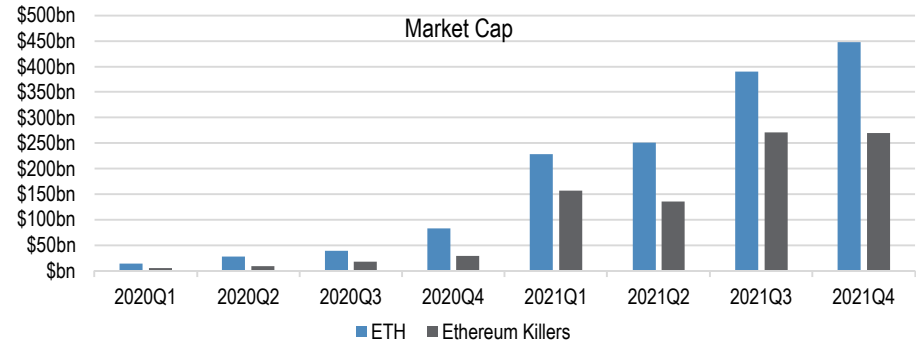
Figure 20: Eth Killers Have Been Chipping Away at the Market Share of Ethereum – That Said, Ethereum's Cap Continues to Grow Smartly

$ in billions



Source: CoinMarketCap.com and J.P. Morgan.

A Brief Review of the Ethereum Killers

- **Solana** - Currently, Solana is one of the fastest-growing cryptocurrencies. Its developers have claimed that it can process around 50,000 transactions per second (TPS), whereas Ethereum currently processes 15-45 TPS. SOL has over 400 projects running on its ecosystem, including stablecoins like Circle's USD. It also runs wallets, decentralized exchanges, and other decentralized finance projects.

- **Cardano** - Cardano was launched by one of Ethereum's co-founders, Charles Hoskinson. It has taken a research-intensive approach to the development, with each stage peer-reviewed and thoroughly tested before implementation. Cardano is now also launching its smart contract capabilities. This third-generation cryptocurrency is considered more scalable than Ethereum.

- **Polkadot** - Polkadot aims to solve some of Ethereum's scalability and cost issues. But Polkadot shines in its interoperability capabilities as it enables blockchains to communicate effectively. This approach also makes it easier for developers to switch to Polkadot's system.

- **Tezos** - Tezos is a user-focused, open-source project that allows users to weigh on project governance and the direction of the blockchain. In addition, Tezos provides well-regarded security and modularity, and is viewed as more scalable.

- **Others Layer-1 Chains** – Other Layer-1 chains viewed as the collections of Ethereum Killers includes Avalanche, Zcash, Binance Coin, Near Protocol, Stellar and Chainlink.

Layer-2 Solutions and Rollups

Layer-2 blockchains are essentially overlay networks that lay on top of the underlying Layer-1 blockchains. Layer-2 on Ethereum chains help scale an application by processing transactions off of the Ethereum Mainnet (layer 1) while still maintaining the same security measures and decentralization as the mainnet. Layer 2 solutions can increase throughput (transaction speed) and can reduce gas fees, but can keep transactions secure, speedy, and decentralized.

Rollups are solutions that perform transaction *execution* outside the main Ethereum chain (layer 1) driving the better speed and lower transaction costs, but post transaction *data* on layer-1 maintaining the security and interoperability. Inheriting the security properties of layer-1 while performing execution outside of layer-1 is a defining characteristic of rollups.

There are two categories of layer-2 rollups: optimistic and zero-knowledge. While both have their advantages and disadvantages, both execute transactions offchain but post transaction data on layer-1. Examples of Layer-2s are below.

- **Polygon** - It is an emerging platform meant to develop and connect Ethereum-based blockchain networks. It features tools and components used by developers to create optimized Ethereum instances. Also, the platform provides an improvement in flexibility for developers and the security of Ethereum.

- **Arbitrum** - It is another Layer 2 solution with features meant for close interoperability with Ethereum. These features make it easy for Solidity developers to cross-compile their smart contracts. The three components of Arbitum include a compiler, the EthBridge and validators. Arbitum does not feature a native token.

- **Optimism** - This is an example of an Ethereum scaling solution that provides improvements to transaction affordability. It can also ensure meaningful improvements in transaction speed for Ethereum users. Developers here can create Solidity smart contracts.

- **Immutable-X** - Immutable-X is a Layer 2 scaling solution for NFTs on Ethereum. It provides instant trade confirmation, zero gas fees, scalability and provides this without compromising user custody.

- **X-Dai** - is a sidechain based on Ethereum and supports users in processing transactions at economical costs and faster speeds. The platform uses a PoS consensus mechanic to help users place native xDAI tokens as stakes on the networks. The most enticing part about xDAI is that it is a stablecoin.

Making Ethereum Better -- The Ethereum Merge

Ethereum is undertaking a significant upgrade that is expected to improve the performance and scalability of Ethereum. The upgrade, referred to as the Ethereum Merge, has been long delayed, but is expected to be executed mid-2022 and will convert Ethereum from a proof-of-work to proof-of-stake. It will ultimately set Ethereum for greater scalability, greater transaction speeds and lower transaction costs.

The more immediate benefits of the merge come from the migration to the Proof-of-Stake protocol, which will drive an immediate improvement in energy efficiency, decentralization and security. Over time, there is the potential for improvements in transaction speeds from ~15 transactions per second today to potentially 100,000 TPS, according to Ethereum founder, Vitalik Buterin. For a primer on Staking including a discussion on the Ethereum merge, see our note.

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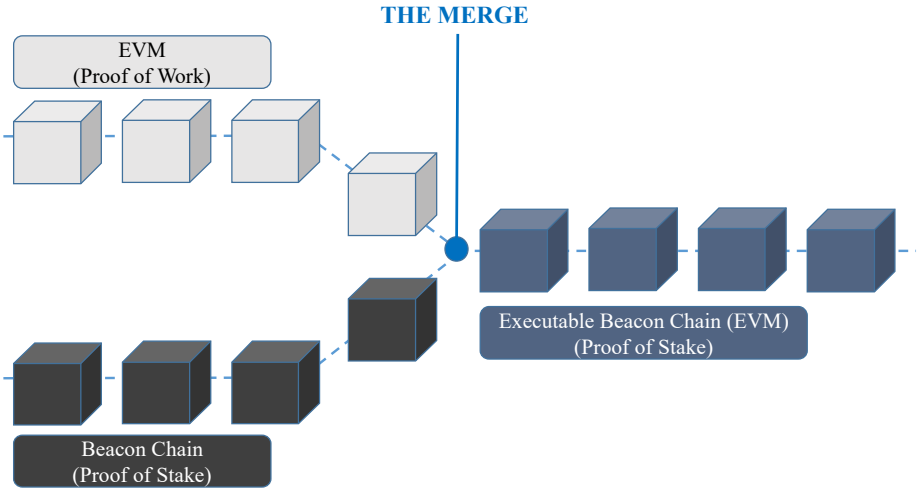
Figure 21: The Ethereum Merge and the Migration to Proof-of-Stake



Source: Consensys and J.P. Morgan.

Ethereum The Evolving Blockchain -- The Ethereum Foundation

We see Ethereum as an Evolving Blockchain that undergoes a number of key upgrades each year. With other blockchains like Bitcoin largely static with just one upgrade in the last four years, Ethereum supports numerous upgrades. Governance is informal for Ethereum and happens off-chain. Upgrades to the core Ethereum blockchain are proposed via Ethereum Improvement Proposals (EIPs) that specify new features or processes for Ethereum. The Ethereum Foundation operates as a non-profit organization that promotes and supports research, development, and education to produce decentralized applications, hosts an allcoredevs call where EIPs are proposed and debated. Participants on allcoredevs calls include developers from the Ethereum Foundation, researchers from other organizations (including Consensys, Nethermind, Sigma Prime, Prysematic Labs) and other volunteers. EIPs are considered, debated, championed, tested, and if all goes well are ultimately implemented on the Ethereum mainnet.

There were four upgrades of the Ethereum blockchain in 2021, including Berlin in April, London in August, Altair in October, and Arrow Glacier in December. The London Hark Fork included EIP-1559 that takes a portion of gas fees in Eth that were paid to miners and 'burns' them, thus eliminating supply of Eth and reducing inflation. EIP-1559 also incorporated variable block sizes that are up to 2x larger to help with capacity issues. The London upgrade included other proposals EIP-3554, EIP-3529, EIP-3198 and EIP-3541 that will help facilitate the transition to proof-of-stake and the Ethereum merge expected in mid-2022.

What Is Happening in the Ethereum Merge

The Ethereum merge refers to merger between the current Ethereum mainnet (PoW) with the Ethereum Beacon Chain (PoS). The Beacon Chain has been running in parallel to Ethereum Mainnet since Dec 1, 2020. To facilitate the migration from Ethereum Mainnet to the Ethereum Beacon Chain, a mechanism called a difficulty bomb will detonate, making mining unprofitable to disincentivizing miners from keeping the chain alive after the network merges, and should/will ultimately represent the end of the Ethereum Mainnet.

Benefits of Ethereum 2.0 and the Beacon Chain

1) Less Energy Consumption – Ethereum is expected to use 99.95% less energy when it converts to proof-of-stake following the merge. When Ethereum converts to proof-of-stake, the selection process to validate the blockchain will migrate from solving the cryptographic puzzles to token ownership. Those that own more Ethereum and/or own it longer will have a greater chance of adding blocks to the Ethereum blockchain and earn a reward. The software required to validate an Ethereum block in proof-of-stake can be done on a laptop with expected electricity costs of $150/year. The proof-of-work protocol used to validate the Bitcoin and Ethereum blockchains consumes significant energy as miners seek to calculate the nonce. Currently Ethereum mining is estimated to consume ~44.5TWh/year in aggregate, on the magnitude of the energy Honduras consumed in 2016.

2) Ethereum scalability – Ethereum 2.0 plans to scale its capacity by using a method called sharding, that is hoped/expected will greatly increase transaction speeds, potentially scaling its ability to 100,000 transactions per second or more. Sharding is a way to partition a database into smaller pieces, spreading execution into 64 new shard chains that are more manageable. With a PoW blockchain, most nodes, or computers in the network, have an entire copy of the history of transactions. This entire history can take up a lot of space, especially for older cryptocurrencies with a long history of transactions. With sharding on PoS, the blockchain is cut up into parallel sections, and nodes are assigned to one section instead of having to hold the entirety of the chain's data. This allows more transactions to be processed simultaneously, greatly increasing throughput and transaction speed. Sharding is expected after the Ethereum merge, toward year-end 2022 or 2023.

3) Ethereum Deflation – We believe that Ethereum issuance could be deflationary following the merge. Inflation takes place when new tokens are mined (in the case of proof-of-work) or minting (in the case of proof-of-stake) as part of the rewards given to those that are adding blocks and validating the blockchains. However, we estimate that the migration from proof-of-work to proof-of-stake combined with the burn introduced in EIP-1559 could drive Ethereum to deflation and negative token issuance. We estimate that Ethereum's inflation rate was ~4.2% annually prior to the implementation of EIP-1559. Block rewards of 2 Eth for mining Ethereum blocks resulted in ~13,000Eth created each day @2eth x 6,500 blocks/day. However, EIP-1559 is driving Eth to be burned (taken out of existence) as a portion of the gas fee is now burnt rather than paid to the miners. We note that since the introduction of EIP-1559, Eth issuance has declined 66% and when transaction activity is particularly elevated, Eth can be deflationary.

Table 2: Burned Rewards since the Introduction of EIP-1559 through Jan 3, 2022

	ETH	USD Equivalent
Burned	1,342,310	$4,964,190,183
Rewards	2,031,053	$7,511,321,476
Tips	249,467	$922,587,702
Net Issuance	688,743	$2,547,138,435

Source: watchtheburn.com and J.P. Morgan.

We expect that following the merge that Ethereum will enter a deflationary period. The rewards for miners total 2-Eth per block, ~4.8mn Eth created each year. However, rewards for proof-of-stake appear far lower for validators, ~0.0052Eth. This lower reward is justified by the far lower resources that validation required under proof-of-stake. But it also means that with far lower block rewards under proof-of-stake that the burn will likely result in deflation, which depending on transaction levels and gas-prices could burn 1-2mn Eth/year.

What's Next for CryptoCurrencies

We think it important to think about outlook for the cryptomarkets based on use cases and potential. We are confident only in that we're probably not doing justice to all the potential applications that those tech savvy and creative entrepreneurs will develop in the coming years. Some/much of this potential will be based on improvements in both layer-1 and layer-2 chains and most importantly more certainty around regulation. We conclude this note by walking through a bit more in depth about Web3.0, NFTs, DeFi and the companies that we have encountered in the cryptoecosystem with some help from our J.P. Morgan crypto colleagues Christine Moy and Stoyan Djourov who run Onyx by JPMorgan, J.P. Morgan's blockchain business.

From Web2.0 to Web3.0 – Crypto's Contribution

We are using the web differently today than we did twenty years ago, and we will use it differently twenty years in the future, we suspect. We start with a description of Web3.0 and a brief overview of the earlier world-wide-web.

- Web1.0 – The Web was for consumers of content and was often referred to as the read-only web. The creators were typically developers who built websites that contained information served up mainly in text or image format. Web 1.0 lasted approximately from 1991 to 2004.

- Web2.0 – Web2.0 is often referred to as the read/write web. The Web became a platform and applications were built on the web rather than on desktops. Web2.0 gave us more content creation on social networks, blogs, sharing sites and more. One didn't / doesn't have to be a developer to participate in the creation process. If you want to upload a video and allow millions of people to see it, interact with it, and comment on it, you can do that in Web2.0. Web 2.0's internet was a massive app store, dominated by centralized apps from Google, Facebook and Amazon where monetizations took place via targeted advertising. However, Web2.0 is plagued with security and data breaches since in Web2.0, you don't have any control over your data or how it is stored.

- Web3.0 – Web3.0 is the read/write/intelligence web. It represents a smarter internet. Web3.0 enables a future where distributed users and machines are able to interact with data, value and other counterparties via a substrate of peer-to-peer networks without the need for third parties. Decentralization is a key part of Web3.0, and as such applications either run on blockchains, decentralized networks of many peer to peer nodes (servers), or a combination of the two that forms a cryptoeconomic protocol. These are often referred to as dApps.

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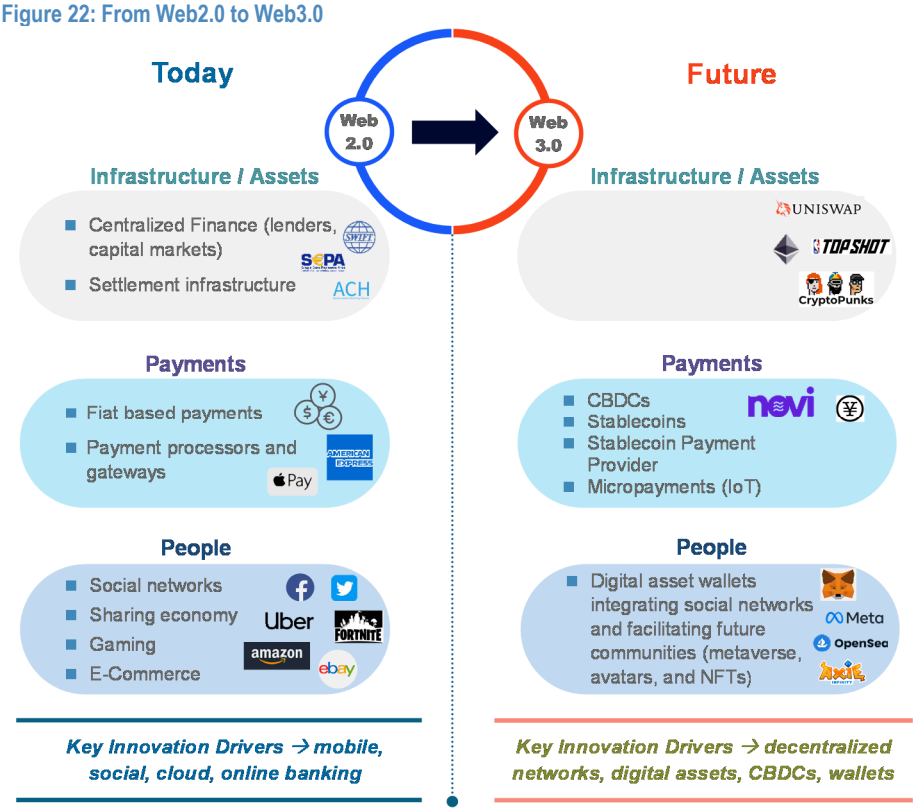
Figure 22: From Web2.0 to Web3.0



Source: Onyx by J.P. Morgan.

Growth in NFTs and the Tokenization of Everything

As mentioned a couple of times in this note, 2021 was the crypto year of the NFT. NFTs have gone from the fringe to the mainstream incredibly fast in areas like art and collectibles, driven not only by the new medium but also by a design that allows creators to build royalties right into the blockchain, empowering the content creator, to some extent to the detriment of the intermediary. Our understanding is that NFTs transformed Art Basil in Miami this past December. But the utilization of NFTs seems likely at its early stages and we see financial services as holding great potential for tokenization broadly. Some use cases for NFTs are as follows.

Figure 23: J.P. Morgan's First Minted NFT as Part of Our CryptoConference

Source: J.P. Morgan

Gaming – The development of games take a bit longer than art or music, and we expect gaming will use NFTs in a much bigger way. Concepts like play-to-earn are developing with NFTs as the assets in the games. Given the interoperability of Ethereum based tokens, we would expect ERC-721 to be the more likely standard utilized in the early development of these games.

NFTs as Tickets – NFTs can be the ticket to a concert, the memento, and the key to unlocking backstage access all in one, but also automatically takes the ticket proceeds and divides them between the artist, the crew, the venue. While the ticket can be made exclusive to cut out the scalpers, tickets that can be resold can automatically allocate any increase in ticket price on resale to the artist, crew and venue so that the content creators benefit from the upside. I'm sure there will be more interesting applications over time.

NFTs in the Metaverse – The metaverse can be a place to store and appreciate NFT art, it's a hub for gaming, it's a virtual reality world. Like gaming, NFTs are positioned to be the assets in the metaverse, with Ethereum as its currency.

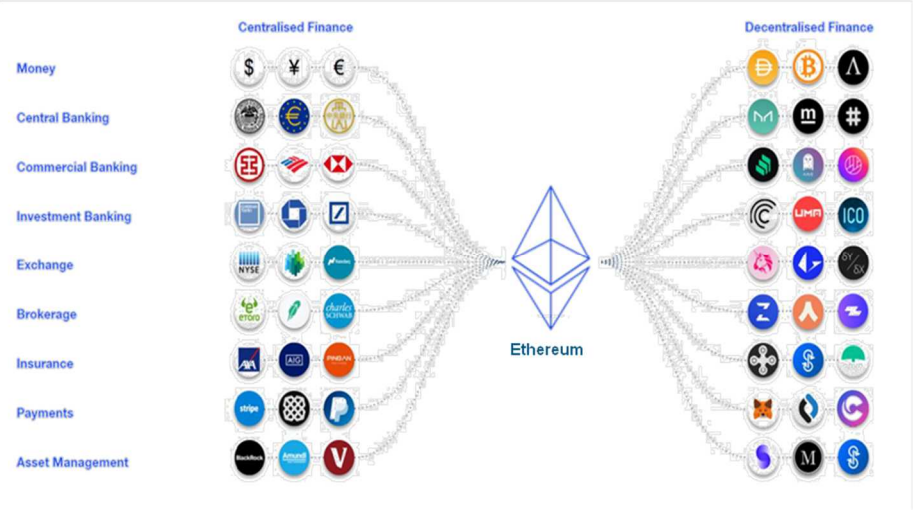
Tokenization of Everything. – Tokenization would seem to hold great potential for financial services, in particular for illiquid assets that could benefit from price discovery, liquidity, asset servicing, and asset composition. Settlement times for equities at T+2 and for credit settlement is T+10+, with some products as long as T+40 would benefit from tokenization. While transaction speeds are too slow for the liquid products, there is the advantage of 24/7/365 trading, in addition to the risk mitigation (and capital relief) that comes with near instant settlement. In our future we see the tokenization (and fractionalization) of credit, equities, parts of real estate (commercial to residential to hotel rooms), and non-traded investments including private equity.

DeFi – The Value of Crypto in Decentralized Finance

Decentralized Finance appears as a large opportunity for cryptomarkets to both participate in and in some cases to disintermediate traditional finance. DeFi is attempting to replicate many or most of the products and services offered by banks, including borrowing, lending, buying insurance, trading derivatives, buying assets,

and earning interest. The existing financial system in the US has functioned for more than a century and operates under a regulatory framework that has been in place since the 1930s and 1940s. DeFi is offering many of the same products and services as traditional financial services firms, but offers them in an updated framework, with the opportunity to operate faster and more efficiently in crypto's peer-to-peer network rather than through system of independent companies and entities. While DeFi inherits many of Ethereum's problems such as speed and cost, we see these problems as solvable and thus see DeFi as presenting a possibly more efficient framework to offer financial services in the future.

Figure 24: Traditional Finance and its Decentralized Finance Challenger



Source: Consensys.

Trad Finance Has Excesses

Our traditional financial system today has more intermediaries than it probably needs. Compare a trade in traditional finance to one for cryptocurrencies. In traditional finance, parties involved in a trade include the mobile app, the broker, the market maker, the exchange, the prime broker, the clearing house, custodian and transfer agent for the buyer and those same financial participants for the seller. In the cryptoecosystem when transacting with a token, there is the buyer, the intermediary and the seller. In the cryptoecosystem, out of necessity and/or by design, the intermediaries are vertically integrated.

Examples of DeFi today

There are a number of examples where DeFi is permeating financial services.

- Lending: Lend out your crypto and earn interest and rewards every minute – not once per month. Lending is based on the collateralization of crypto assets by locking them in smart contracts and borrowing against that collateral. Interest payments, maturity and lifecycle processes are all automated through the protocol. It is estimated that $52bn is the value currently locked in lending protocols such as AAVE and Compound.

- Getting a loan: Obtain a loan instantly without filling in paperwork, including extremely short-term "flash loans" that traditional financial institutions don't offer.

- Making a Payment: Decentralized payment tools designed to facilitate invoicing and payments between merchants and customers. Here, digital-native assets stand out from legacy digital payment methods, such as those run by Visa and PayPal, in that they remove all middlemen from transactions. When you pay with a credit card for coffee at a cafe, a financial institution sits between you and the business, with control over the transaction, retaining the authority to stop or pause it and record it in its private ledger. By paying in cryptocurrencies, those institutions could be cut out of the picture. There is ~$3bn of value locked in decentralized payments in protocols such as Salier.

Stablecoins: Another form of DeFi is the stablecoin. Cryptocurrencies often experience sharper price fluctuations than fiat. Stablecoins peg cryptocurrencies to non-cryptocurrencies, such as the US dollar, in order to keep the price under control. With the ability to send crypto like money, cyptocurrencies could alter the remittance markets, B2B payments and cross-border money transfers. While some see the interchange-fees charged by credit card companies as being at risk, this is not considered the base case for the J.P. Morgan payments team. An example of DeFi in stablecoins is Maker, a platform that collateralizes assets to create a stablecoin.

Trading: Non-custodial automated market making protocols running a decentralized orderbook. Here, order matching and price-setting can be done completely algorithmically, allowing peer-to-peer trades of certain crypto assets without any kind of brokerage. There is ~$31bn locked in Decentralized Exchanges such as Uniswap.

Saving for the future: Put some of your crypto into savings account alternatives and earn better interest rates than you'd typically get from a bank.

Buying derivatives: Tokenized derivatives created without the need for a third party. Counterparty agreements are programmatically encoded, reducing the risk for malicious activity. Make long or short bets on certain assets. Think of these as the crypto version of stock options or futures contracts. There is an estimated $4.1bn locked in DeFi derivative protocols such as Synthetix.

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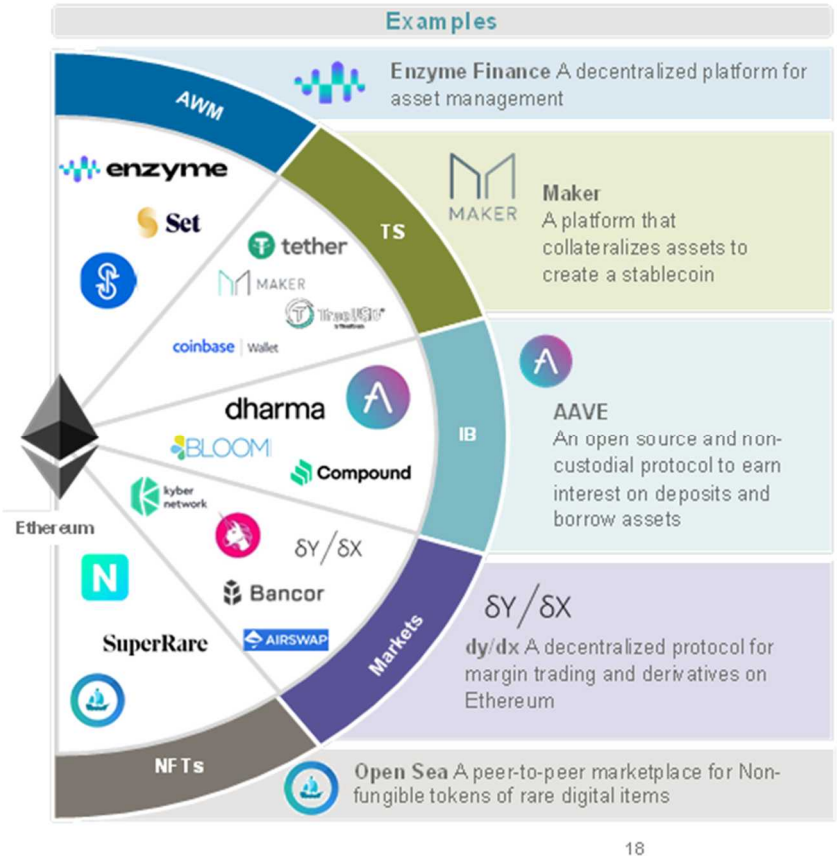
Figure 25: Participants in DeFi Today by Business, Courtesy of Onyx by JPMorgan



Source: Onyx by JPMorgan

Benefits of DeFi

- Decentralization: Decentralization is important because centralized systems and human gatekeepers can limit the speed and sophistication of transactions while offering users less direct control over their money. DeFi is distinct because it expands the use of blockchain from simple value transfer to more complex financial use cases. Cutting out middlemen from all kinds of transactions is one of the primary advantages of decentralized finance.

- Open: You don't need to apply for anything or "open" an account. You just get access by creating a wallet.

- Pseudononymous: You don't need to provide your name, email address, or any personal information.

- Flexible: You can move your assets anywhere at any time, without asking for permission, waiting for long transfers to finish, and paying expensive fees

- Fast: Interest Rates and rewards often update rapidly (as quickly as every 15 seconds), and can be significantly higher than traditional Wall Street.

- Transparent: Everyone involved can see the full set of transactions (private corporations rarely grant that kind of transparency).

The Downside to DeFi

The downside to DeFi is generally based on the shortcomings of Ethereum, off of which most smart contracts, dApps and DeFi are based. As mentioned above, the downside is network congestion and the impact that has on increasing gas costs and transaction expenses. As such, DeFi that results in active transactions can be very expensive. Other issues such as token volatility, the need to monitor transactions for tax purposes and varying regulation from one region to another are also highlighted as risks to DeFi.

Traditional Financial Services Companies Start to Embrace Cryptocurrency Technology.

- Traditional Financial Services firms are servicing clients that want to engage in the cryptoecosystem. There are also examples where financial firms are embracing the cryptoecosystem to make traditional financial offerings better. Here, we see traditional financial services on the front-end, but DeFi powering the back-end. However, we see the current regulatory environment (really the lack of Federal Crypto Rules and Regulation) limiting the presence that traditional finance can have in crypto. There is just too much to lose if new rules are put into place that run contrary to the ways that traditional financial service firms might be engaging with crypto. Nonetheless, financial firms are slowly getting involved, but largely as facilitators.

- Goldman Sachs – Goldman is offering cryptocurrency trading and is offering bitcoin futures and non-deliverable forwards

- Morgan Stanley – Counterpoint Global (Investment Management investing arm) exploring exposure to crypto for investors – pending approval from the firm and regulators.

- J.P. Morgan Chase – The firm has also built an intraday repo system and is a leader in this space with more than $200 billion in repo transactions done so far

- Fidelity Digital – Offering trade execution services for Bitcoin, along with cold storage custody. Also, integrated ErisX (a Fidelity investment) as first exchange in addition to other market-making trading firms which internally match orders routed from Fidelity DA

- Deutsche Bank – Creating a trading and token issuance platform via a partnership with prime brokers, issuers and vetted exchanges. Part of a wider plan to create crypto services, including digital asset custody

- Susquehanna – Reportedly trades Bitcoin, Ether, Bitcoin Cash and Bitcoin futures for a limited client base

- Jump Trading – One of the most active firms in crypto market and providers of liquidity to exchanges (e.g., reportedly Robinhood, Bitfinex). Reportedly has built a BTC OTC platform to facilitate trades

- StateStreet – State Street Digital announced it is working with blockchain securities startup Digital Securities Depository Corporation (DSDC) to provide custody services for digital depositary receipts (DDR). DSDC operates a

blockchain platform for regulated financial institutions that enables Americans to trade UK stocks

- US Bank – U.S. Bank, the 5th largest bank in the U.S., launched its crypto custody program with NYDIG, a major bitcoin investment firm. The new service supports institutional crypto funds invested in Bitcoin, Bitcoin Cash and Litecoin

- Visa – Visa has announced the launch of a Universal Payments Channel (UPC) that will support transactions between stablecoins and CBDCs, enabling blockchain interoperability and cross border payments

- CME – Launched Bitcoin Futures in Dec 2017 and Ether Futures in Feb 2021, Bitcoin micro futures in May 2021 and Ether micro futures in Nov 2021

- CBOE – CBOE launched Bitcoin futures in Dec 2017, but abandoned the project in Mar 2018. CBOE announced the acquisition of digital asset infrastructure company ErisX in Oct 2021

Participants in the Vast Cryptoecosystem

We'll call the participants in the cryptoecosystem a work in progress. But there are the companies that are touching the vast cryptoecosystem and have entered our field of vision.

Figure 26: Identifying the Players in the Cryptoecosystem

Source: The Block Research.

Correction: We corrected Figures 24-26.

Companies Discussed in This Report (all prices in this report as of market close on 06 January 2022)
Coinbase(COIN/$234.00/OW)

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Coinbase (COIN, COIN US) Price Chart

Date	Rating	Price ($)	Price Target ($)
25-May-21	OW	225.30	371
09-Aug-21	OW	258.26	372
21-Oct-21	OW	314.71	375
09-Nov-21	OW	353.92	447

Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage May 25, 2021. All share prices are as of market close on the previous business day.

The chart(s) show J.P. Morgan's continuing coverage of the stocks; the current analysts may or may not have covered it over the entire period.
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	Overweight (buy)	Neutral (hold)	Underweight (sell)
J.P. Morgan Global Equity Research Coverage*	52%	37%	11%
IB clients**	53%	46%	34%
JPMS Equity Research Coverage*	51%	37%	12%
IB clients**	74%	68%	50%

*Please note that the percentages might not add to 100% because of rounding.
**Percentage of subject companies within each of the "buy," "hold" and "sell" categories for which J.P. Morgan has provided investment banking services within the previous 12 months.
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