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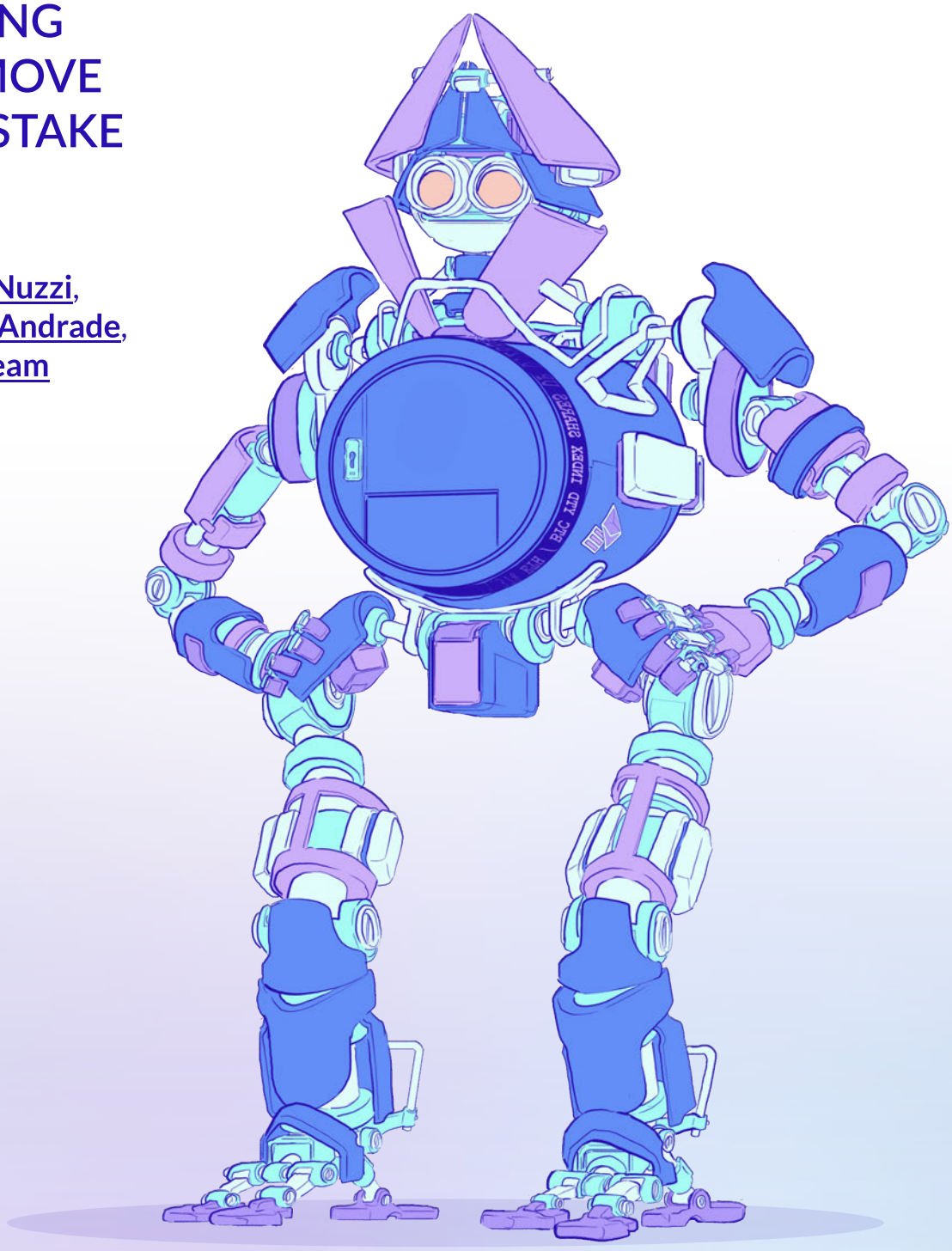
MAPPING OUT THE MERGE

UNDERSTANDING ETHEREUM'S MOVE TO PROOF OF STAKE

By Kyle Waters, Lucas Nuzzi, Nate Maddrey, Matías Andrade, and the Coin Metrics Team



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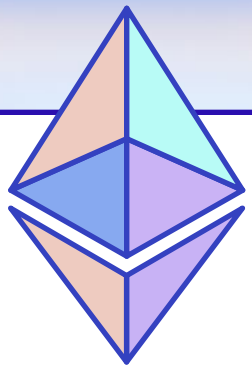

MAPPING OUT THE MERGE

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After years of research and development, The Merge will transition Ethereum to Proof of Stake fundamentally changing the network's security and economics, and realizing the most significant upgrade since its 2015 launch. Ethereum's developers are determined to complete the change while avoiding any impacts to the billions of dollars worth of assets secured on-chain and millions of worldwide users. The Merge will not be a panacea for Ethereum, but will set the groundwork for the next act in the network's ambitious and exciting future roadmap. In this special report, we break down the most important moving parts of The Merge and its implications for the future of Ethereum.

EXECUTIVE SUMMARY

- "The Merge" is the long-awaited event that will retire Proof-of-Work mining on Ethereum in favor of an alternative mechanism called Proof-of-Stake which is run by validators who lockup or stake their ether (ETH) to earn rewards for securing the network. This is Ethereum's most significant change to date since its 2015 launch and has profound implications on the network's security, economics, and global energy impact.

- Although The Merge constitutes a monumental shift for Ethereum, it has been designed to minimize any impact on existing Ethereum users and applications. Current ETH holders do not need to move or touch their assets for The Merge, and no downtime is expected if all goes according to plan. From the user's perspective, the experience of making a transaction on Ethereum will look and feel the same after The Merge.

- Operationally, The Merge will link the present day Ethereum blockchain that executes user transactions and powers Ethereum applications to another blockchain called the Beacon Chain, which forms the backbone of Proof-of-Stake and has been running in parallel to the execution layer since its launch in late 2020. After The Merge, Ethereum will be composed of the pre-Merge **execution layer,** where users make transactions, and the Beacon Chain **consensus layer**, responsible for processing new transactions and building new blocks.

- Ethereum's economics are changing dramatically. Unlike in Proof-of-Work, the amount of ETH issued will follow a dynamic schedule, increasing as the amount of staked ETH increases. At today's level of staked ETH (13M) yearly issuance is set to drop from ~5M ETH under Proof-of-Work to ~600K ETH under Proof-of-Stake—close to a 90% reduction. Accounting for the burning of transaction fees, ETH is likely to be a deflationary asset in the immediate years after The Merge.

- Staking recasts ETH into a yield-generating asset. Expected staking rewards move inversely with the total number of validators (users staking ETH). At today's rate, the typical validator will likely earn returns of 4.5% per year from rewards alone. After The Merge, validators will earn *additional* yield from user-paid transaction fees on the execution layer and maximal extractable value (MEV).

- The Merge is just one step in an ambitious set of future upgrades for Ethereum. While The Merge itself will not immediately solve scalability constraints, it does lay the foundation for future improvements. But The Merge isn't free of risks. Even if The Merge is executed flawlessly, the move to Proof-of-Stake raises new questions about the potential centralizing forces of liquid staking pools and custodial staking services.

INTRO TO THE MERGE

Often described as "changing the engine while in flight," Ethereum's upcoming transition to Proof-of-Stake through The Merge will fundamentally change Ethereum's security model and its economics. If all goes to plan, the change will occur while the Ethereum chain stays up and running—without any down time.

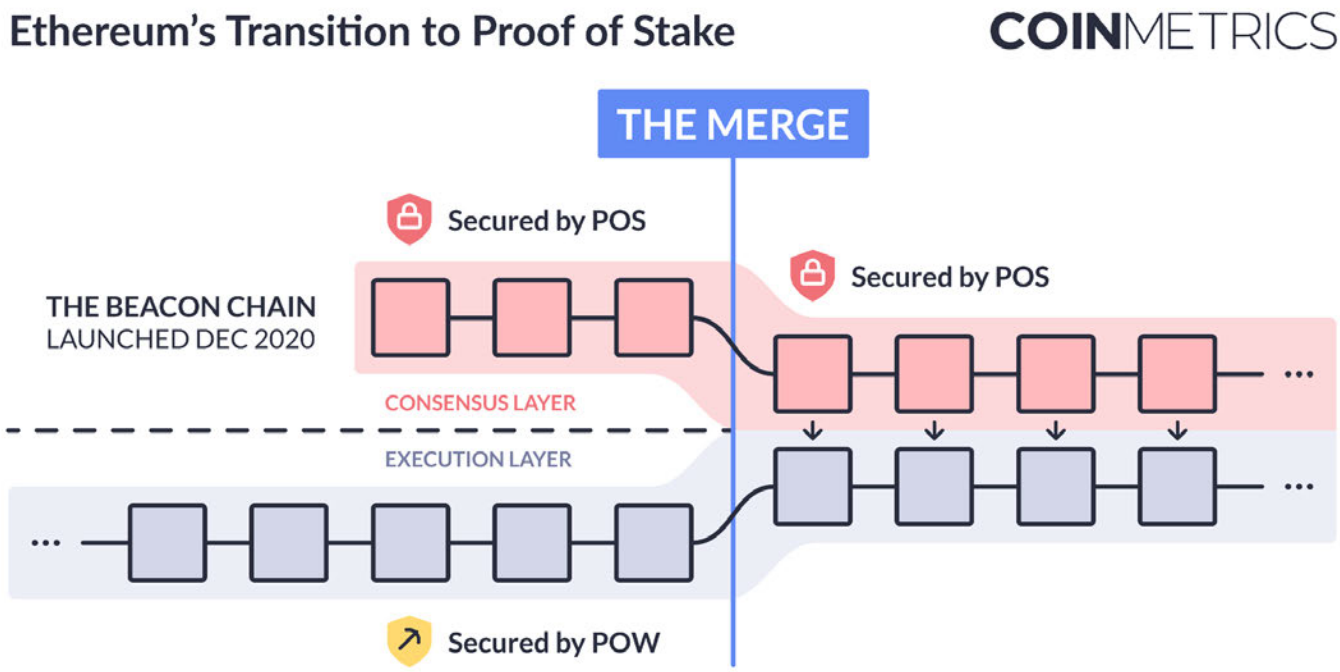
Following years of research and development and three "mock" Merges in 2022, Ethereum's consensus mechanism will transition from a Bitcoin-like Proof of Work (PoW) to Proof-of-Stake (PoS), realizing one of the earliest and most important goals in an ambitious roadmap[1] intended to improve Ethereum's security, scalability, and sustainability. Instead of miners, post-Merge Ethereum will have "validators." Validators facilitate block production and contribute to the security of the network by verifying the changes in account balances, or state, enacted by every new block. In order to participate, validators need to stake Ethereum's native ether (ETH) token (hence the name "Proof-of-Stake") to earn ETH rewards—so long as they act honestly.

This upcoming network upgrade is called "The Merge" because two blockchains, today running in parallel, will be linked together turning Ethereum into a modular system. The first is the present-day Ethereum Mainnet that users know best. This is Ethereum's execution layer because it empowers the execution of the smart contracts powering decentralized applications (DApps), tokens, and more. The second is the Beacon Chain, the blockchain that introduced PoS to Ethereum when it launched in December 2020. The Beacon Chain is Ethereum's consensus layer because all activity occurring on the chain today is related to Ethereum's Proof-of-Stake consensus mechanism.

The Beacon Chain has already been running now for over a year and a half and is currently producing blocks (without being able to influence activity on the execution layer) and issuing ETH rewards for stakers just like it will after The Merge. The Beacon Chain is the chief coordinator of Ethereum PoS and maintains a ledger of validator balances while orchestrating their duties. The Beacon Chain is a special-purpose blockchain and the Beacon Chain won't have smart contracts or an execution environment, so it can't run DApps or create new tokens.

[1] Note that The Merge and other major planned network upgrades were previously branded as "Ethereum 2.0" or "ETH2." The Ethereum Foundation has since moved away from this nomenclature to avoid confusing users into thinking, among other things, that there will be two distinct native ether tokens, which there will not be.

But this is exactly by design and The Merge will combine the Beacon Chain consensus layer with Ethereum's current execution layer, preserving Ethereum's entire state history while swapping out PoW mining on Mainnet today, as shown in the diagram below.



In addition to the impact on network security, The Merge will dramatically change Ethereum's economics. Newly issued ETH will drop from about 13.5K to 1.67K a day at today's amount of staked ETH. Taking into account the burning of fees introduced with EIP-1559, ETH will likely be deflationary in the near term. As mining becomes obsolete, validators (also referred to as stakers) will become the primary economic actors in Ethereum's consensus mechanism. They will earn all block rewards via newly issued ETH and will also earn the transaction fees that miners currently earn as "priority tips," much like the system in place. The Merge also generates a vibrant set of new questions surrounding the impact of so-called "liquid staking derivatives," and the evolution of maximal extractable value, or MEV.

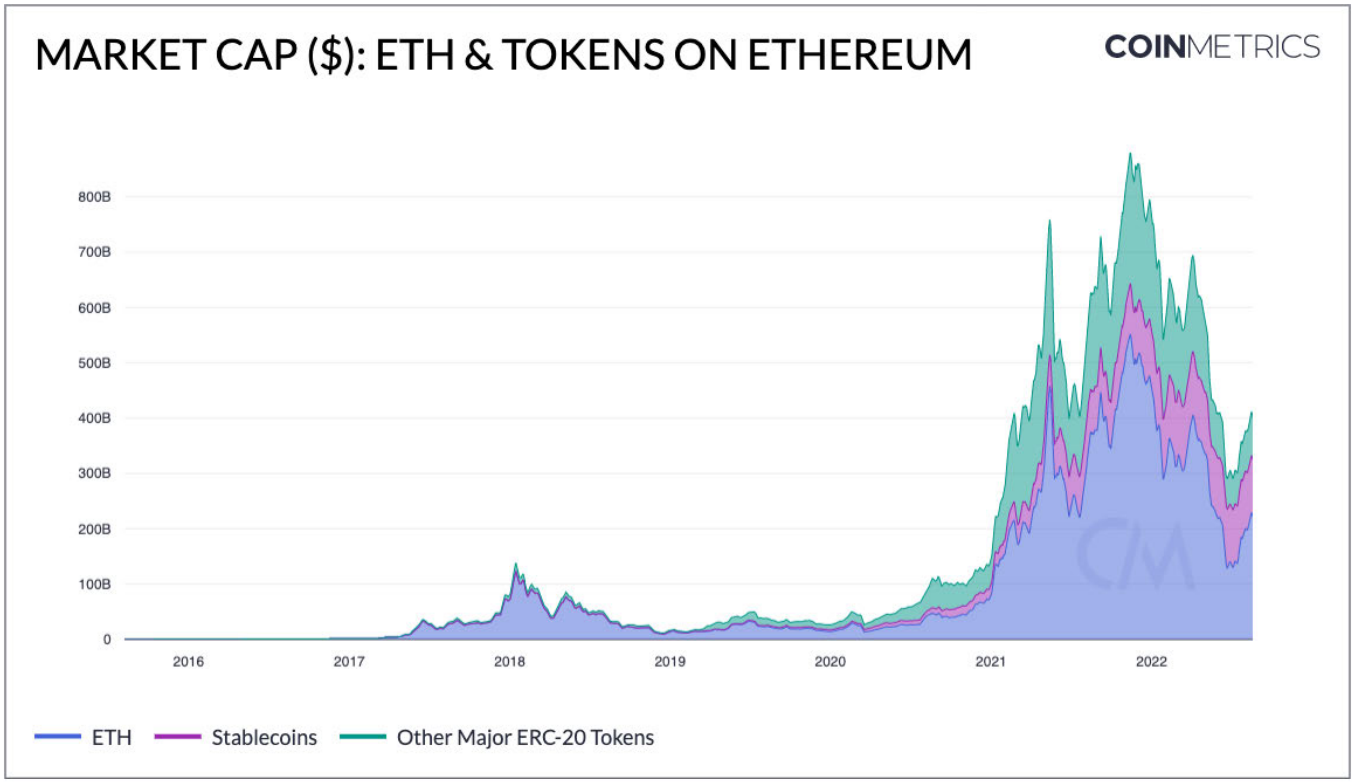
The Merge will be a big upgrade for Ethereum in many ways but it will not be a panacea. It is a misconception that The Merge will immediately solve scalability issues, or help reduce gas fees. In reality, users should expect a familiar system both in terms of transactional capacity and fee dynamics as those will remain the same post-Merge. Nevertheless, this new system is instrumental for future scaling technologies, and should profoundly impact how Ethereum grows and evolves in the years to come.

This report will first introduce the core concepts of Ethereum's Proof-of-Stake consensus mechanism before breaking down the sweeping changes of The Merge on ETH's economics. Next, we briefly survey the current Ethereum roadmap and how The Merge lays the groundwork for the future of Ethereum. We conclude with a short reflection on the end of Ethereum mining, before discussing important on-chain data impacts of The Merge as well as some potential risks.

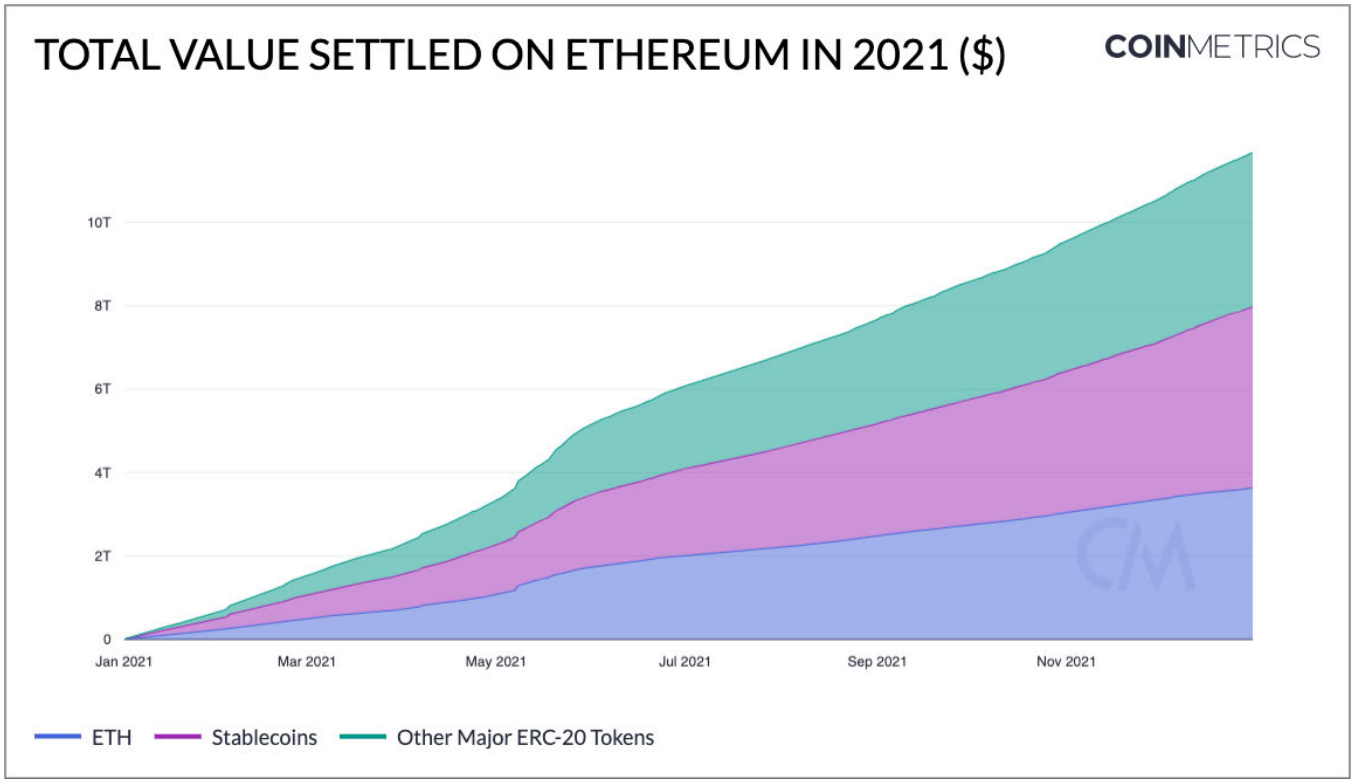
THE BASICS OF ETHEREUM PROOF OF STAKE

The Path to PoS

Since its launch in 2015, Ethereum has evolved into one of the most vibrant centers of the crypto-economy. Not only is ETH the second-largest crypto asset by market capitalization at over $200B today, it also boasts the most dynamic decentralized finance (DeFi) ecosystem with over $100B in stablecoins circulating on the smart contract platform and many billions worth of other tokens built on top of the blockchain. Decentralized exchanges (DEXs) process volumes at times comparable to their centralized counterparts, while valuable non-fungible tokens (NFTs) empower a new creator economy. Every day, Ethereum settles tens of billions of dollars worth of value for its millions of users with zero downtime. On the tailwinds of DeFi's rapid growth, Ethereum settled a total of $11.6T in 2021.



Source: Coin Metrics Network Data



Source: Coin Metrics Network Data

Ethereum's economic significance has meant that the path to upgrading the network's consensus mechanism has been both relatively conservative and iterative. Developers have focused on minimizing disruption to current Ethereum users, and plan on introducing as few "breaking changes" as possible to the execution layer post-Merge. Given the breadth of applications operating in the existing system, the goal appears to be maintaining constant uptime throughout the network upgrade. Knowing that Ethereum secures billions in value has also meaningfully contributed to the design decisions and guiding principles of the new PoS consensus mechanism.

A secure consensus mechanism is a vital feature of a globally accessible, decentralized public blockchain. Without it, the network is subject to attacks and cannot provide reasonable settlement assurances to its users. In general, a consensus mechanism lays out a set of rules and economic incentives to help independent blockchain nodes (i.e. distributed network of computers) come to agreement on important information, like who owns what, while ensuring network security by incentivizing collaboration instead of hostility.

At a high level, both PoW and PoS keep stakeholders honest by imposing real-world costs on those who attempt to engage in fraudulent behavior. In the case of PoW, miners expend electricity to guess a number by effectively "brute-forcing" several results as quickly as possible. The network can safely assume miners have "skin in the game" because they successfully solved the hash of the block, implying they've likely invested a substantial amount of capital into efficient hardware, infrastructure, and electricity over a meaningful period of time. In PoS, participants vote with their assets, or stake, which cannot be spent while they are engaged in this activity. Fundamentally, the goal of both systems is the same: to make the cost of attack prohibitively expensive. Would-be attackers need to procure immense amounts of the scarce resource in question—electricity in PoW, capital in PoS—in order to attempt an attack.

This means that ETH commanding a high value is one of the core prerequisites for PoS to function properly. Not only does this make it harder to accumulate the necessary resources to attack the chain, but it also makes losing staked ETH more costly. Stakers commit ETH to receive rewards but also run the risk of being penalized, or slashed, for poor performance and bad behavior. In this way, staked ETH provides Sybil resistance, accountability, and incentive alignment. Thankfully, Ethereum's PoW years have helped establish ETH as a valuable crypto asset and, thus far, the only asset in the Ethereum network that can be used for this purpose.

The main motivations for The Merge and move to PoS are to make Ethereum more secure and less energy intensive, while also creating a scaffold for future scalability improvements. With the desire to move to PoS even predating Ethereum's network genesis[2], The Merge represents the culmination of years of development and testing by Ethereum core developers and researchers. Ethereum will certainly not be the first PoS crypto asset, but implants new design elements into its specific implementation.

Excitement has mounted throughout summer 2022 as Ethereum has completed three dramatic tests of The Merge on the Ropsten (June 6), Sepolia (July 6), and Goerli (August 11) testnets (Ethereum testing environments). Following the Goerli testnet, developers were confident in moving forward with the real thing, with The Merge on Ethereum mainnet scheduled for a total terminal difficulty (TTD)—a proxy of total mining hashes computed—of $5.875*10^{22}$. As of August 29, this is currently projected for September 15, 2022.

[2] One of the earliest posts to the Ethereum Foundation blog (January 15, 2014) ponders PoS as a consensus mechanism. PoS was also the motivation for Ethereum's *time-bomb*.

While the immediacy of The Merge excites, it's important first to understand that the transition to PoS has actively been in the works for over a year and a half already, with the first critical phase towards The Merge—the launch of the Beacon Chain—going live in December 2020.

An Intro to the Beacon Chain: Ethereum's Consensus Layer

The late 2020 launch of the Beacon Chain officially kickstarted Ethereum's transition to PoS. The Beacon Chain[3] is a blockchain specially designed to facilitate PoS for Ethereum. To understand how Ethereum will operate post-Merge, it is necessary to become acquainted with the Beacon Chain. While the Beacon Chain is a blockchain, it's very different from the Ethereum Virtual Machine (EVM) powered execution layer with smart contracts and Dapps. The exact details of the Beacon Chain are intricate and technical, but some of the key ideas are presented below.[4]

The primary function of the Beacon Chain is to manage Ethereum's validators, who complete the necessary duties to make PoS work. Validators are users that have staked the current system-required amount of 32 ETH[5] and operate validating nodes for the network. The Beacon Chain chooses at random which validators will propose new blocks in the system and issues rewards and penalties to these validators based on their performance at regular intervals. As noted earlier, the Beacon Chain's core role in building consensus is the motivation for calling it Ethereum's "consensus layer."

Unlike most existing blockchains where time is measured in blocks, time in the Beacon Chain is measured in two new units: epochs and slots. A slot is an opportunity for a new block to be added and is exactly 12 seconds long. Some slots might not contain a block which can happen if the validator chosen to propose at that slot is offline, for example.

[3] The name "Beacon Chain" is a reference to randomness beacons, which provide a public source of randomness.
[4] For a more technical overview, check out the specifications of the Beacon Chain here and Ben Edgington's Upgrading Ethereum, a useful technical handbook on Ethereum's move to PoS.
[5] 32 ETH was chosen as a compromise between an amount low enough for solo/retail stakers to feasibly participate, while restricting total validator count to manage network overhead. Note that this amount could potentially change in the future.

An epoch is simply a collection of 32 consecutive slots and is intended to last 6.4 minutes (32 x 12 / 60). Together, epochs and slots set the cadence for block production, rewards, penalties, and other important actions related to the PoS consensus system.[6]

The Beacon Chain has been producing blocks and handing out rewards to validators just like it will post-Merge since its launch. As of writing, the Beacon Chain is currently through 141,000 epochs and 4.5M slots with 4.4M blocks produced with roughly 740K new ETH issued to validators (net of penalties and slashings). But without any connection to user transactions on the execution layer, these blocks are effectively devoid of any real economic activity other than staking rewards, penalties, as well as the basic operational backbone of the system. The Merge will change all of that once the Consensus Layer and Execution Layer become linked.

The Relationship between the Beacon Chain and Execution Layer

A good way to grasp the role of the Beacon Chain is to understand its relationship with the current execution layer. The connection between the Beacon Chain consensus layer and execution layer is essentially a one-way street. As we will cover in this section, users that desire to become validators must deposit funds onto a contract in the execution layer that effectively locks them up. These funds are then "recreated" in the consensus layer, thereby enabling users to validate blocks and receive staking rewards. For the near future, those funds will remain in the consensus layer.

The Beacon Chain has been developed in relative isolation to the stable Ethereum execution layer users are most familiar with. This has allowed for testing to be completed without disruption to Ethereum applications. The relationship today between the consensus layer (Beacon Chain) and execution layer (Ethereum mainnet today) is limited to the registering of new validators. For an Ethereum account to enter the validator set today, it must deposit ETH to the official staking contract[7] that exists on the execution layer / Ethereum mainnet. At the moment, ETH can only flow one-way to the Beacon Chain from the execution layer. Withdrawals from the Beacon Chain to the execution layer will eventually be allowed, but not immediately at the time of The Merge.

[6] Such as attestations, committees, the activation or exit of validators, slashings, and a long list of other procedural items.
[7] 0x00000000219ab540356cbb839cbe05303d7705fa on Ethereum mainnet.

Launching the Beacon Chain over a year and half ago has given participants plenty of time to deposit their 32 ETH and set up the hardware and software required to run validating nodes.[8] It has also enabled a sizable amount of stake to accumulate, which increases the security of the Beacon Chain and makes for a safer Merge. As of August 19, 2022, just over 13.3M ETH has been deposited to the staking contract for a total of 416K active validators. This is just about 11% of Ethereum's current supply.

Total ETH Staked and Number of Validators

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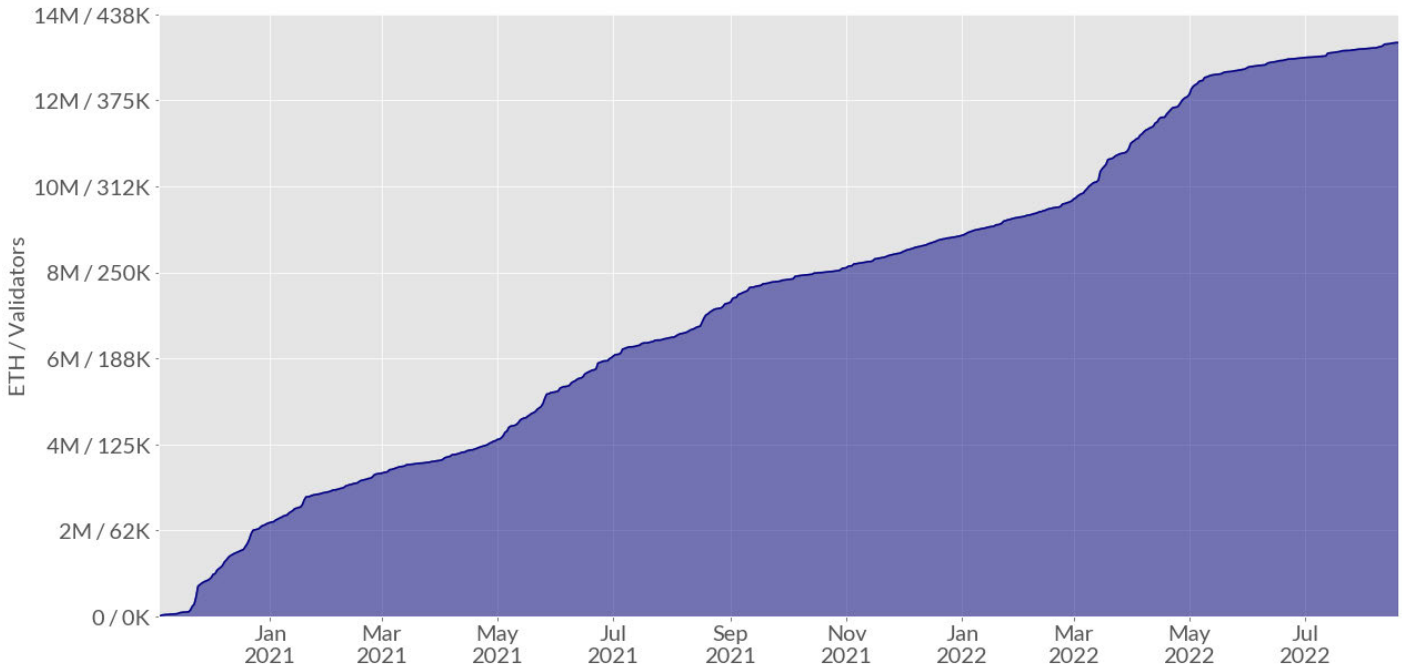
Source: Coin Metrics Labs



However, the relationship between the Beacon Chain and Ethereum's present-day execution layer will change with The Merge. From the viewpoint of an Ethereum user, not all that much will change.[9] But in the background, the Beacon Chain will be driving Ethereum block production with miners no longer responsible for adding new blocks to the chain.

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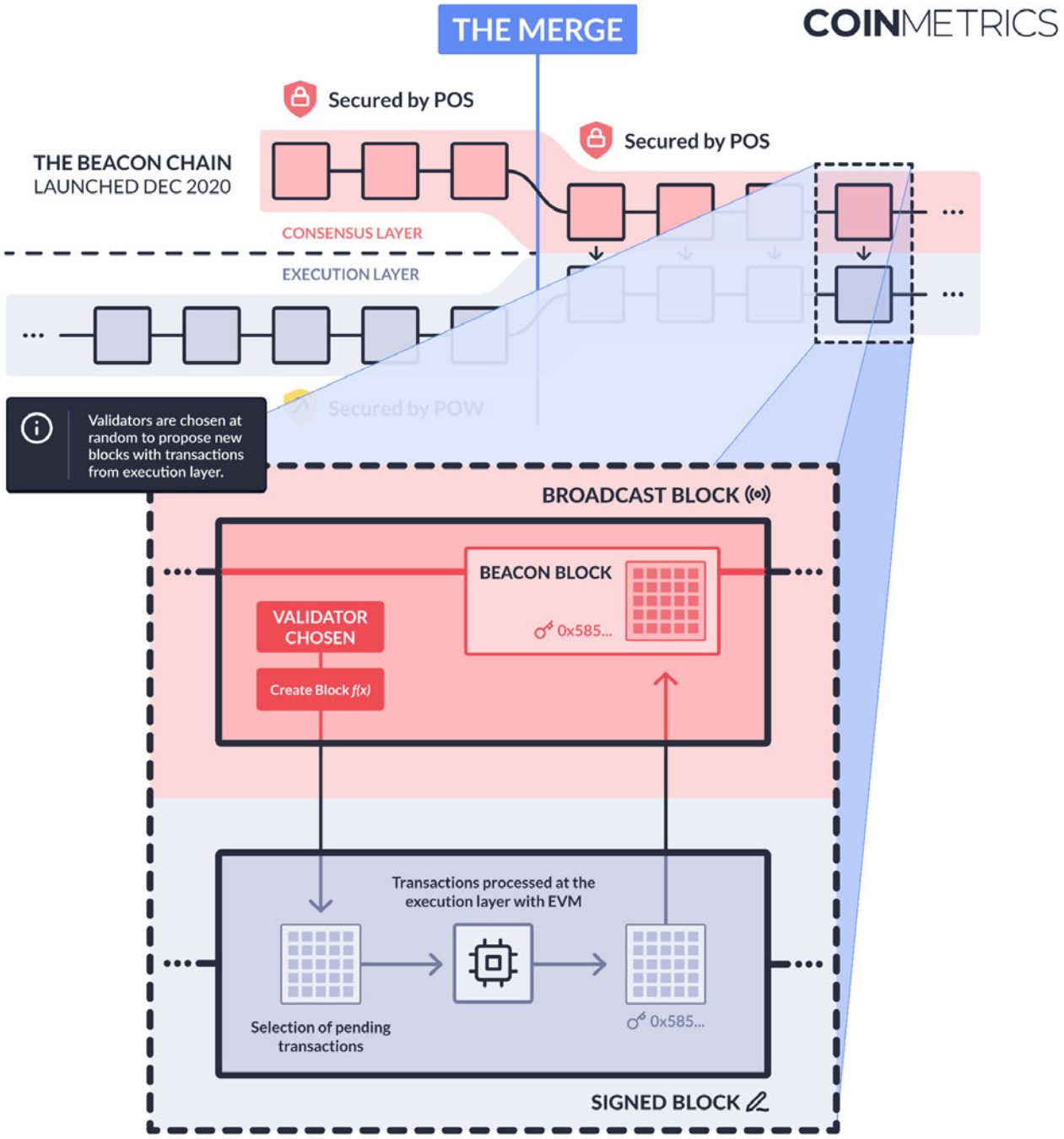
[8] At the time of writing, validators can operate nodes using performant, but accessible consumer hardware. This is in contrast to the specialized graphics processing units (GPUs) that Ethereum mining currently requires. However, post-Merge validators need to operate two clients (Ethereum software implementations) for both the execution and consensus layers. This introduces some complexity as there are different clients for each layer, and node operators need to choose a pairing.

[9] Barring any issues with the execution of The Merge itself, it is anticipated that The Merge will introduce very few breaking changes to Ethereum applications.

To understand this better, the diagram below shows the interaction of the Beacon Chain and execution layer after The Merge. Note that this is a very simplified version of the exact mechanics but conveys the main idea.[10]



[10] For a more technical deep dive into the relationship between the consensus and execution layers check out this post from Ethereum Foundation researcher Danny Ryan.

Every 12 seconds, one validator is chosen randomly[11] from the set of active validators on the Beacon Chain to propose a new block at a slot—a roughly 1 in 416,000 chance today. That lucky validator then runs software that allows them to pick and choose user transactions that have pooled on the execution layer—known as the transaction mempool—to construct a valid block. Some of these user transactions will be high priority and offer lucrative fees to the proposer for their transaction to be selected. This valuable on-chain economic activity; be it an NFT mint, swap on Uniswap, transfer of USDC, is executed and collected into a valid block before being transmitted to the Beacon Chain where it is broadcast to other validators along with with all staking activity that took place at that time.

Just like in Proof-of-Work, the entity or user producing a block, in this case our lucky validator, has the power to decide which transactions will be included. A key difference in Proof-of-Stake is that, once a validator has broadcast a block, other validators need to look at its content and attest to it. If all goes well, the validator who proposed the block is given a reward for doing so on the Beacon Chain while also receiving user transaction fees on the execution layer. Validators who attested to the block are also given smaller rewards for their efforts.

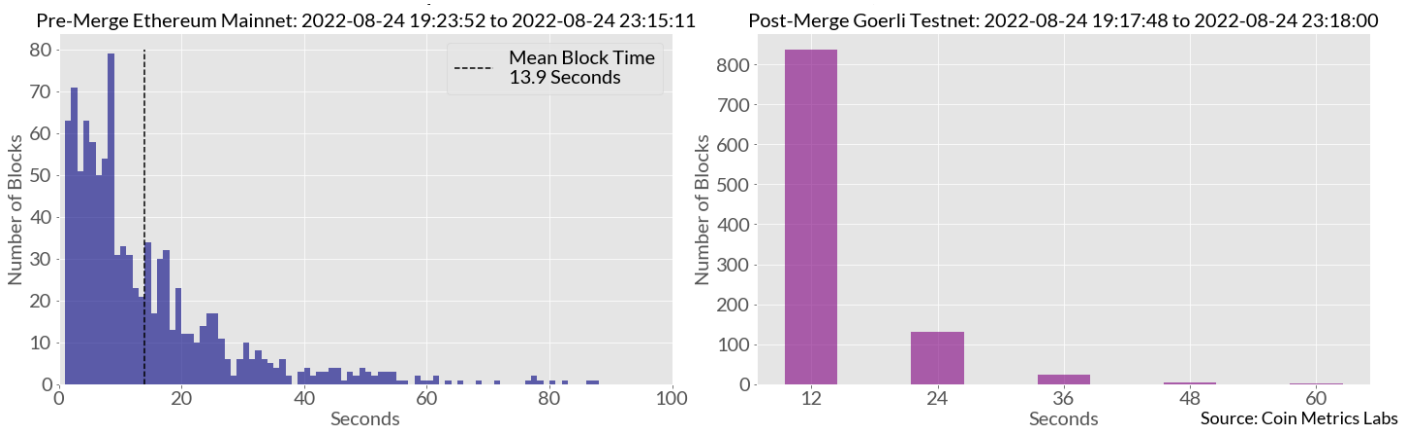
A welcome byproduct of this system of validators and attesters is an increase in efficiency, especially as it relates to block times (i.e., the time between two blocks). One immediate result of the Beacon Chain controlling new block creation for Ethereum is that block times will drop to exactly 12 seconds assuming perfect validator performance and low network latency. Under PoW, block times can vary due to mining following a Poisson process. Over time, PoW blocks average 13.5 seconds but by the very nature of mining, block time is impossible to predict. To illustrate this, the chart below shows the distribution of block times for a 1,000 block sample (just under 4 hours) on Ethereum mainnet today pre-Merge and the Goerli Ethereum testnet, which successfully underwent The Merge in early August.[12]

[11] In practice, pseudo-randomly. The Beacon Chain uses a random number generator called RANDAO.
[12] Coin Metrics has been running nodes for all of the Ethereum testnets in preparation for The Merge.

Comparison of Block Time Distributions, PoW vs. PoS

COINMETRICS

Source: Coin Metrics Labs



In practice, block times will not be exactly 12 seconds due to the imperfect participation of validators—especially on a testnet where there are no real financial consequences. Post-Merge, participation should be higher and lead to a drop in average block times compared to the PoW era. This effectively brings a small increase to Ethereum's throughput.

The main takeaway from above is that post-Merge, Ethereum relies entirely on validators from the Beacon Chain to process and finalize[13] new transactions. With miners out of the picture, they will control which transactions will be included in each new block and be responsible for the progression of the blockchain. To correctly align incentives and ensure that validators actually do their jobs well, there are economic consequences for their actions. These economic decisions dictate a validator's expected returns and profoundly impact ETH's economics as a whole.

[13] Note the concept of "finality" in blockchains is a nuanced one and requires deeper discussion beyond the scope of this report. For a taste, readers can refer to this post from Ethereum co-founder Vitalik Buterin.

ETHEREUM VALIDATOR ECONOMICS

The subject of economics has always been an essential discipline to crypto. In the following sections, we examine Ethereum's economics, starting at the microeconomic level and focusing on the validator as the key economic agent under Ethereum PoS. We then zoom out and consider the macroeconomics of Ethereum before and after The Merge.

Validator Rewards and Penalties

Under the pre-Merge PoW era, the rewards that miners receive for their work are straightforward: a flat block reward of 2 ETH for finding a new block and any 'priority' fees or miner tips collected on user transactions. Ethereum's system of "uncle" or "ommer" block rewards adds another layer of complexity, but overall revenue to miners is easy to infer.[14]

Under PoS, there are relatively more variables to consider when breaking down the financial returns to being a validator and putting capital in the form of ETH to work in the system. First, there are many different ways that validators are rewarded on the Beacon Chain. Most of the time, validators will be attesting to (voting on) new blocks—exactly once per epoch—but will also get the chance occasionally to propose new blocks, as described earlier. The rewards for these various duties are all given specific weightings on the Beacon Chain.

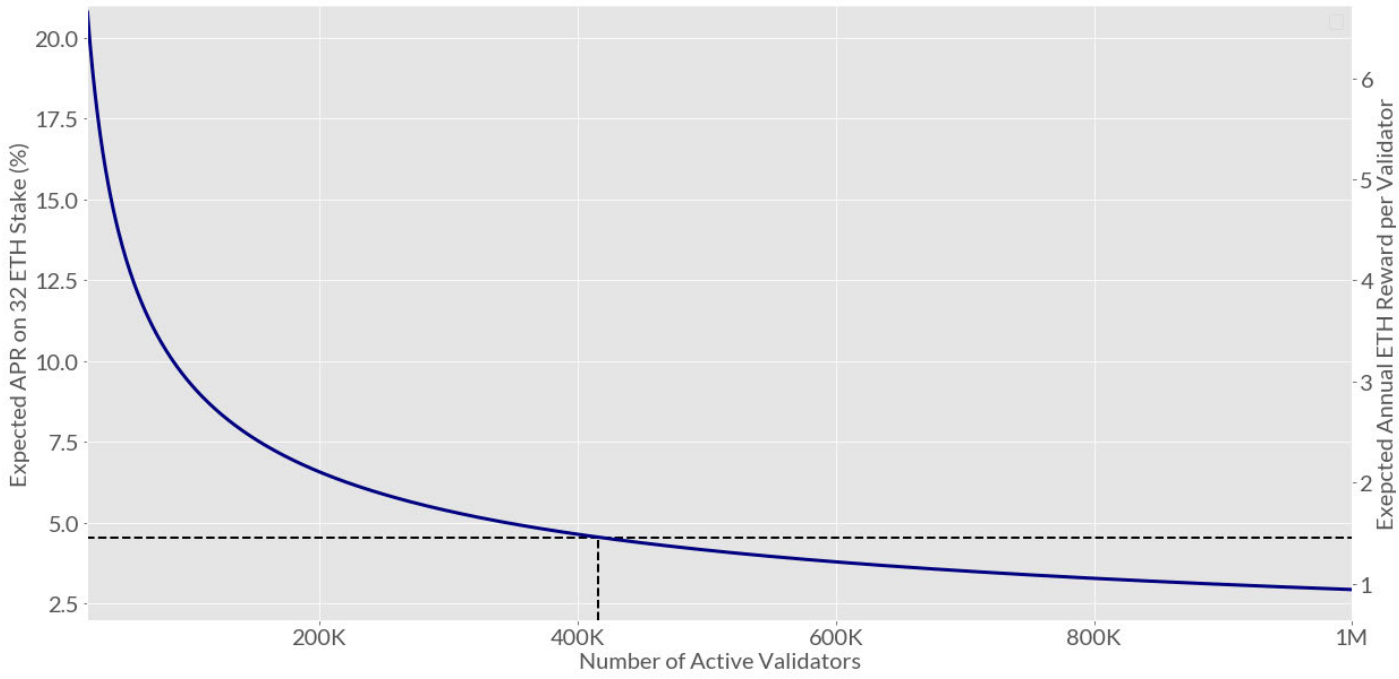
[14] While the revenue side of mining might be simple, the *cost* side is arguably more complicated compared to staking. Mining at scale generally requires negotiating energy contracts with utility companies, and understanding constantly changing hardware competitiveness.

Critically, the total expected reward to an individual validator scales up or down with the total number of validators on the Beacon Chain. The chart below shows the per validator expected annual yield and ETH reward from staking assuming perfect performance.[15] At 416,000 validators at time of writing, this implies a best-case annual return of 4.56% or 1.459 ETH from staking rewards alone for the typical validator.

Expected Annual Percentage Return For Validators

COINMETRICS

Source: Coin Metrics Labs



In addition to validator rewards on the Beacon Chain, there will be an additional source of revenue received by validators on the execution layer after The Merge: priority fees, sometimes called miner tips. The tip is a voluntary portion of the fees users pay to transact on Ethereum. This additional reward is used by transactors that wish to prioritize their inclusion in the next few blocks. Ethereum users have always paid transaction fees, but the concept of a priority fee was introduced with EIP-1559, Ethereum's major upgrade to its fee market in August 2021 (to learn more about EIP-1559 and how Ethereum's fee market operates today check out our report on the subject here). Under the current PoW regime, this tip is given to Ethereum miners.

[15] A validator maintains what is known as an effective balance which caps out at 32 ETH and goes down with bad performance and bad behavior. Rewards scale with the effective balance and validators with less than 32 ETH in effective balance receive less. Carrying a balance of more than 32 ETH provides no additional benefit today to stakers.

But after The Merge it will be disbursed to validators proposing new blocks, in addition to the rewards already received on the Beacon Chain.

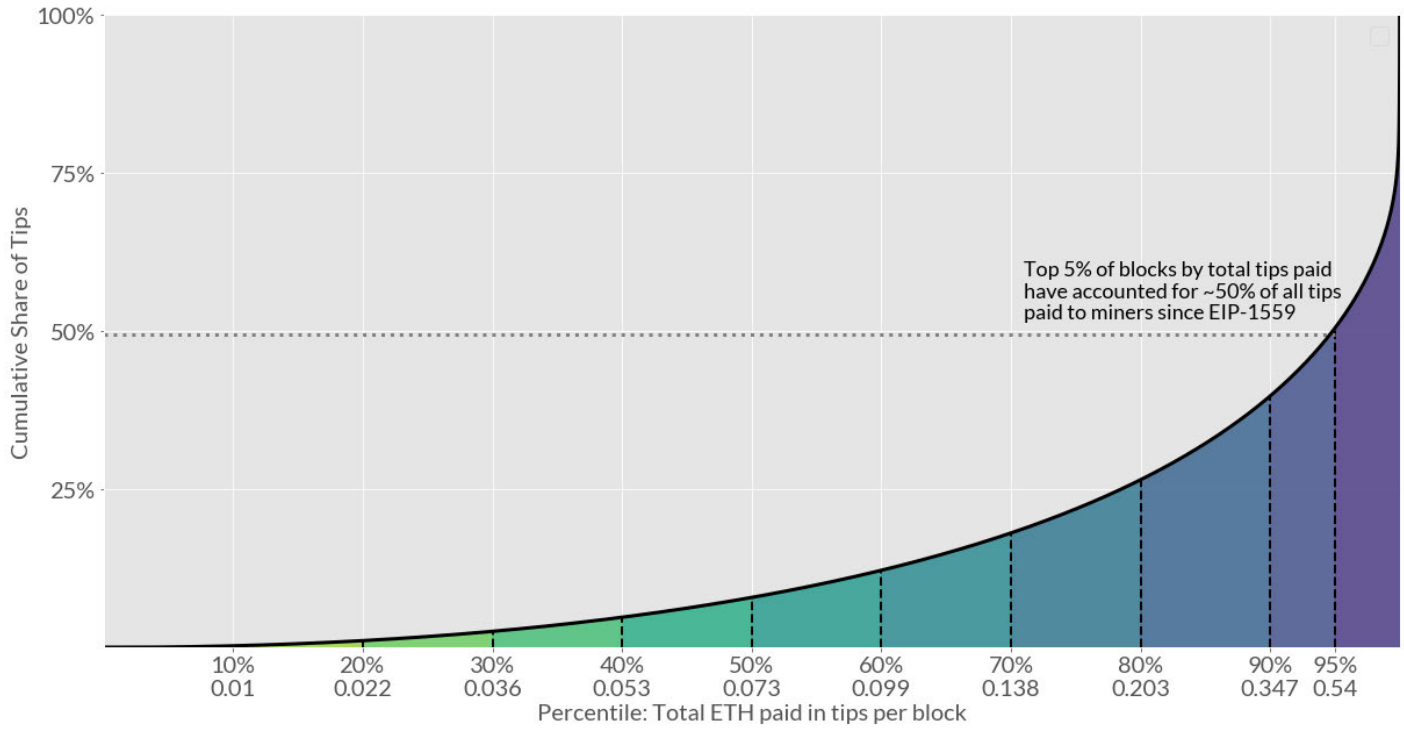
A complete estimate of a validator's returns should take into account not only ETH that is issued, but also the tips on the execution layer. Nevertheless, it's important to note that the distribution of tips to miners today is highly variable so validator yield will change as demand for block space in the execution layer increases. While most miners today receive a modest fee, periods of high demand for block space can lead to outsized payouts.

The graph below shows that the highest 5% of Ethereum blocks by total tips paid by users accounted for about half of all tips distributed to miners since EIP-1559's launch (2.3M block sample). Put differently, miners have received less than 0.54 ETH in 95% of blocks.

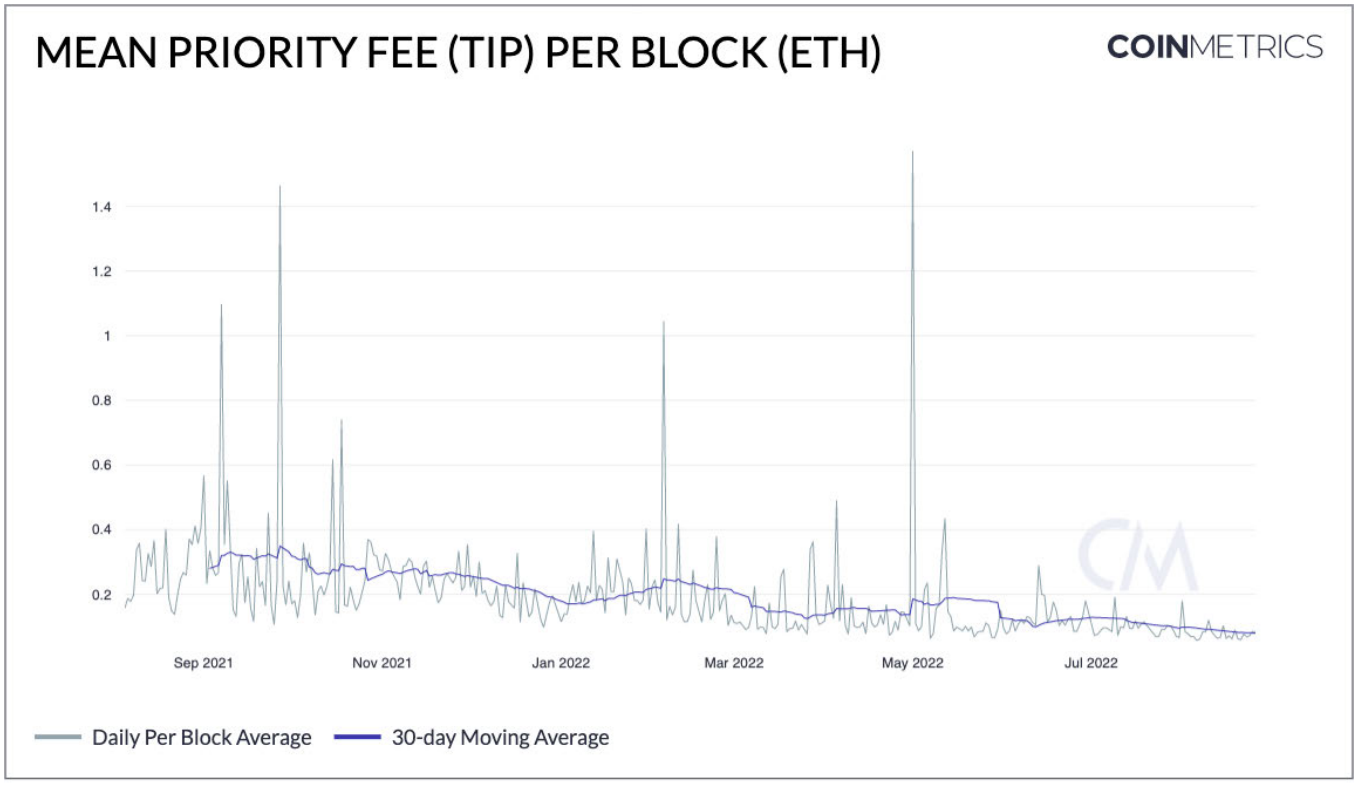
Distribution of Priority Fees on Ethereum by Block

COINMETRICS

Source: Coin Metrics Network Data Pro



This distribution has also been far from stationary, rising and falling with demand for transacting on Ethereum. The median per block tip in January 2022 was 0.085 ETH and only 0.047 ETH in July 2022. The chart below shows the mean tip received per block by day, with noticeable spikiness.



Source: Coin Metrics Network Data Pro

The cyclicality of Ethereum's economy on top of the uneven distribution makes yield estimates a challenge in practice, but if we consider the median per block tip of ~0.073 ETH since EIP-1559's launch and the expected number of blocks a validator will propose per year with 416,000 active validators of 6 blocks[16], we can estimate what the yield on staked ETH might be including tips as 1.459 + 0.438 = 1.897 ETH, or a total yield of 5.93% per year. Under extreme circumstances, it's even possible that tip revenues could dwarf all other validator rewards for some lucky validators.[17]

[16] Assuming perfect participation and 416K active validators, there is simply a 1 in 416,000 chance of a particular validator being selected to propose a block at a given slot. With 31,557,600 seconds in a year and 12 seconds per slot this is 2,629,800 slots in a year. Thus, the expected number of chances to be a block proposer in a year is 6.32 = (1/416,000) * (2,629,800). This will of course scale up or down with the number of active validators.

[17] During the unprecedented demand for Ethereum blockspace in the May 2022 Bored Ape Yacht Club 'Otherside' NFT mint, one miner received tips totaling 7,678 ETH (~$22M at the time) in a single block.

Validators will also have the opportunity to receive maximal/miner extractable value, or MEV. MEV is the economic benefit captured by block producers (miners in PoW, validators in PoS) from ordering, excluding, or including transactions in an advantageous way when adding new blocks to the chain. The rise of DeFi and decentralized exchanges (DEXs) on Ethereum has increased the importance of transaction ordering with opportunities to capitalize on arbitrage and other strategies.

Flashbots, an MEV research unit, estimates that miners have earned at least $240M in payment for MEV over the past two years. There are many ways MEV is set to change with The Merge, but among them two stand out. First, in contrast to PoW where the production of new blocks is a race between miners, the block proposer under PoS is known a short time in advance. Second, the set of unique block proposers in PoS is far larger than the set of dominant mining pools under PoW. With this new design space, MEV is likely to continue evolving after The Merge. The exact channels through which validators will extract MEV opportunities is a rich field of current research.[18]

Most of the yield estimates above assume that every node is executing its duties perfectly, without being penalized or slashed. But in practice, many nodes in the Beacon Chain have been penalized, in most cases, due to downtime. Validators can be penalized for their downtime, which decreases their validator revenues, while slashing is reserved for more serious transgressions, which could form part of a network attack. To protect against any coordinated attack, the slashing is scaled in proportion to the sum of balances slashed in the past 8192 epochs, around 36 days. This mechanism helps to encourage diversity among validators (e.g., different software, geographic locations), as being correlated with the rest of the network during times of distress can lead to steeper losses. Since the protocol was designed to accommodate individual stakers, downtime penalties are relatively lenient.

With good uptime and behavior, a validator will see newly minted ETH start to accumulate on the Beacon Chain. However, an important note about validator rewards today is that they do not compound; any balance above 32 ETH is effectively inert capital that will likely be swept up regularly to put to more productive uses. The ability to partially withdraw funds from the Beacon Chain will not immediately be available to stakers after The Merge. This function is anticipated to be introduced in the first post-Merge upgrade, Shanghai. The accumulation of ETH on the Beacon Chain does raise questions surrounding built-up demand to access staking rewards, but the overall reduction in ETH issuance (see macroeconomics section below) combined with the rise of liquid staking derivatives and popularity of custodial staking services, should alleviate these concerns.

[18] Interested readers can check out Flashbots' writings on MEV and The Merge for more on this subject.

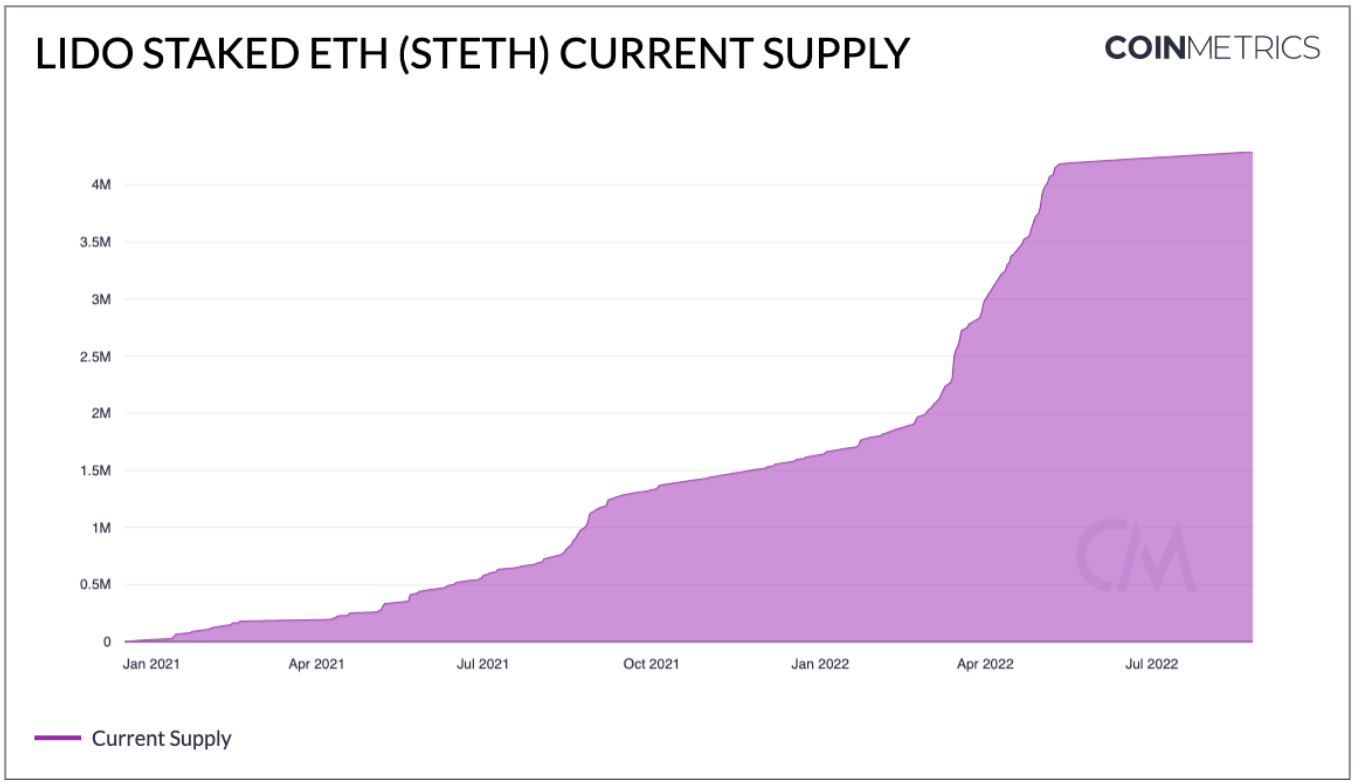
Liquid Staking Derivatives and Staking Services

In an ideal world, all Ethereum users that would like to directly participate in PoS and capture returns on their ETH would run their own nodes and maximize the network's decentralization. While the system has been designed to make it easy for solo stakers, the reality is that independent staking requires the right mix of risk tolerance, technical know-how, and capital needed to become a validator. At time of writing, there are roughly 21M Ethereum addresses holding between 0.01 and 1 ETH, in addition to the many retail users holding their ETH on exchanges. For these relatively smaller holders, staking is only possible through the pooling of funds. Even for addresses with more than 32 ETH that could become validators, it's understandable that staking with an expert can be preferable to maintaining specialized nodes (computers running Ethereum's software clients) that need to run 24/7/365 for maximal returns. Finally, staking with larger pools of validators also allows small to midsize stakers to smooth out their income over time. As discussed above, transaction fees received when proposing blocks can constitute a significant portion of a validator's total income. Yet, for the individual validator, these opportunities will come irregularly over time.[19]

A variety of options have emerged to meet the demand for staking ETH, each coming with its own set of trade-offs and special considerations. Among them, the rise of liquid staking solutions that issue liquid staking derivatives has proved to be one of the most significant developments in the ETH staking landscape. Liquid staking allows users to pool their ETH in increments less than the 32 required to be a validator and earn yield without maintaining their own node infrastructure, with the added feature of receiving tradable tokens that derive their value from claims on the staked ETH. These tokens, known as liquid staking derivatives, have important implications for staking economics and health of the Ethereum protocol.

[19] Joining a pool can also make it easier to become aware of MEV opportunities. The incentives to pool funds and share rewards to smooth out earnings are similar in some ways to the incentive for miners to join mining pools in Proof-of-Work. However, note these incentives are counteracted in Ethereum PoS by the "anti-correlation" mechanisms described earlier whereby harsher penalties are given to validators who are offline when more than ⅓ of the total validators are also offline.

The most popular liquid staking derivative today is Lido's staked ETH (stETH), an ERC20 token that represents ETH locked up in the consensus layer. Lido serves as middleware connecting the ETH capital markets to a whitelisted set of large, professional staking services. The Lido protocol and the node operators take a cut of total rewards as a fee for the service.



Source: Coin Metrics Network Data

Liquid staking derivatives have become popular because they allow users to benefit from the economic profits that are (currently) locked on the consensus layer on the execution layer, where the accumulated ETH can be used for other purposes. This is especially important today without the ability to withdraw ETH from the consensus layer. Because their price will generally[20] track that of underlying spot ETH, liquid staking derivatives have become popular in DeFi on the execution layer, used as collateral in lending protocols such as Maker or Aave and for other productive economic activity, like any other ERC20 token. While Lido's stETH is the most popular today, other liquid staking derivatives exist, including Rocketpool's rETH, and the August 2022-introduced cbETH, representing ETH staked with Coinbase, the major US-based crypto exchange.

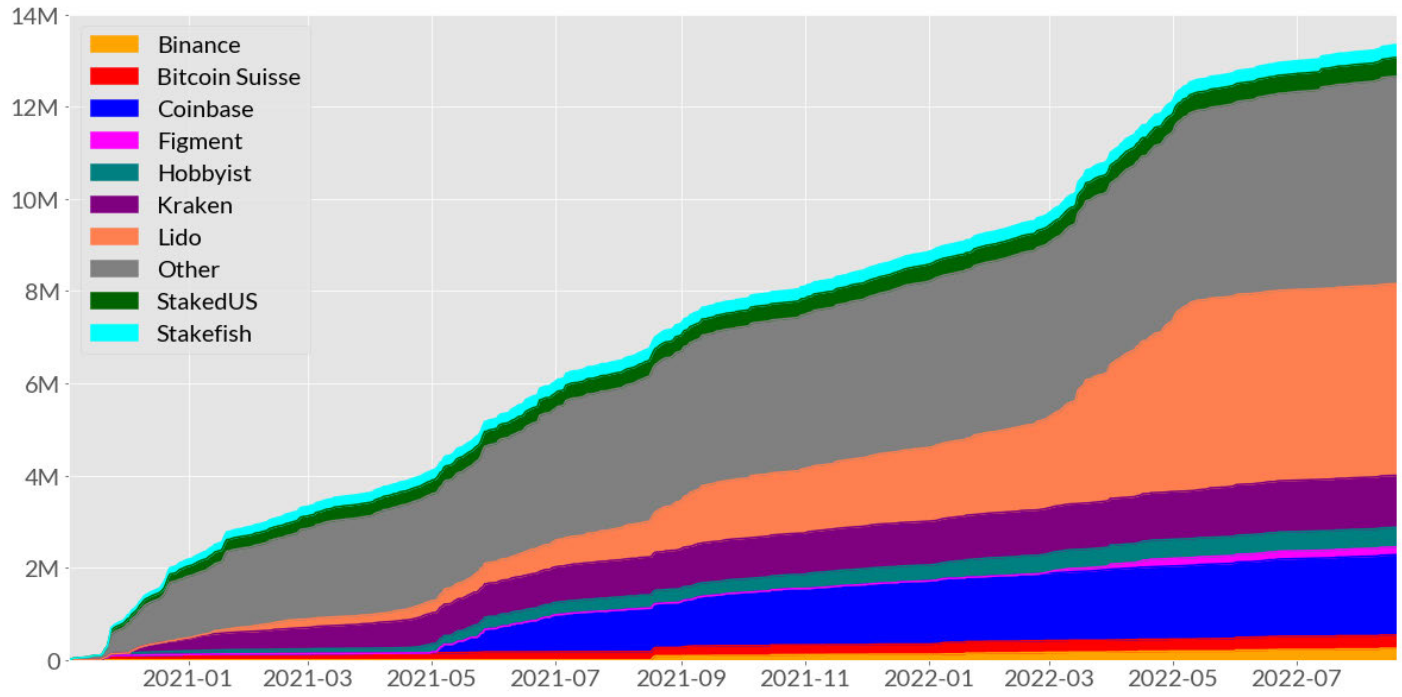
[20] Without the current ability to redeem the underlying ETH, liquidity issues can create short-term deviations from the spot price, as occurred during the crypto market turmoil of spring 2022.

A great number of other products exist that offer different features and cost structures. Staking with centralized crypto exchanges such as Coinbase, Kraken, and Binance has become a popular method of staking. The chart below shows the breakdown of the 13.3M ETH deposited so far to the staking contract, estimating the share of deposits from major staking services and exchanges.

Total ETH sent to Execution Layer Staking Contract, by Depositor

COINMETRICS

Source: Coin Metrics Labs

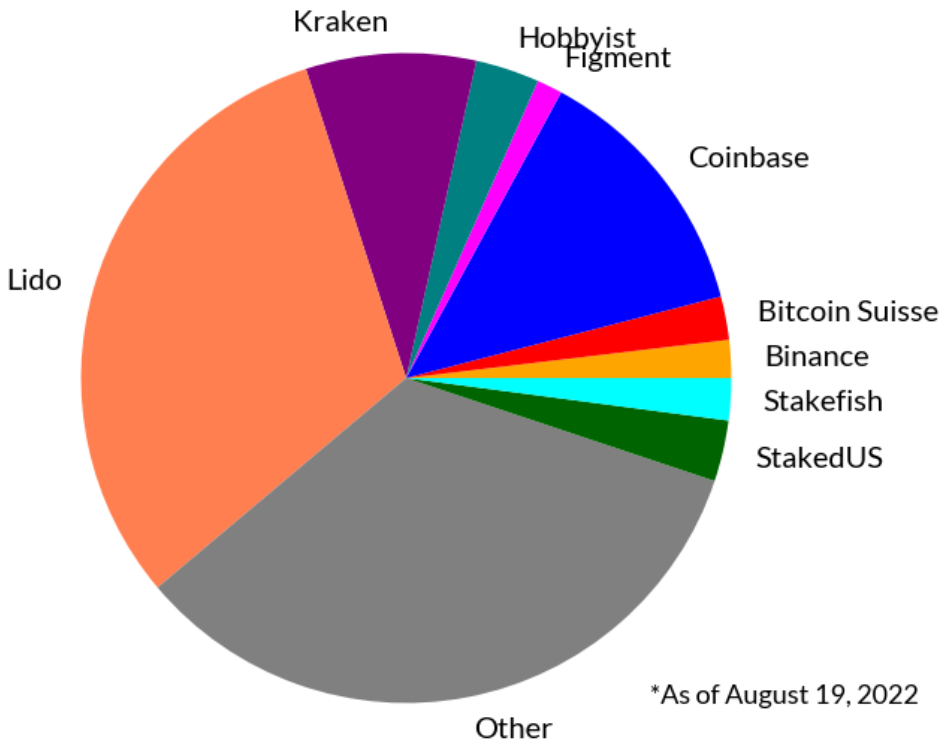


Lido is the single largest source of deposits to the Beacon Chain with around 4.2M ETH deposited with the liquid staking solution, accounting for around 31% of all deposited ETH to date. Coinbase is the second-largest depositor with an estimated share of 13% of all staked ETH. The pie chart below shows the current breakdown as of August 19, 2022. Note that hobbyists are broadly defined as those addresses that have sent the required 32 ETH, but no more.

Share of ETH Deposits to Staking Contract

COINMETRICS

Source: Coin Metrics Labs



This is only a best estimate because accurately tagging blockchain addresses is a difficult exercise. Without the ground truth and confirmation of which address belongs to which entity, there can be a degree of uncertainty. Some entities are very easy to track because they only use one address to carry out deposits. Lido, for example, is simply a single smart contract (0xae7...E84) on the Ethereum blockchain. But other entities, like Coinbase, choose to generate new addresses for each deposit.

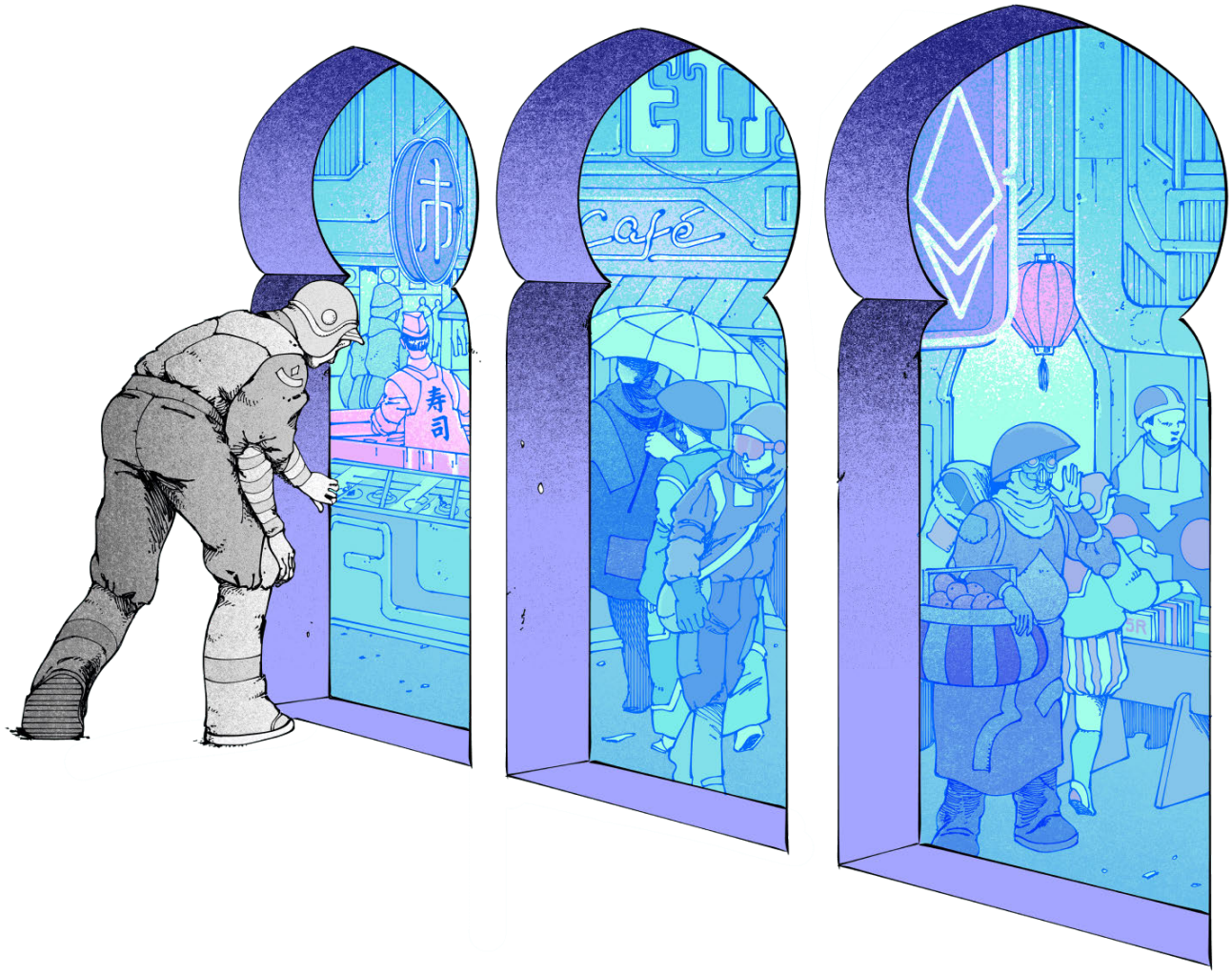
This requires identifying the relevant on-chain patterns and building heuristics to tag addresses fitting the mold.[21] We have taken a conservative approach above, only including tags that we have a high degree of confidence in, thus possibly understating some exchanges' shares. This is an area we are actively researching.

The distribution of staked ETH is important to track for reasons extending beyond the basic economics of staking. For starters, if one entity captures too large of a stake this can introduce fragilities to the network; if that entity's nodes go down all at once—perhaps due to human error or concentration of hardware geographically—it can impact network uptime. Further, an overly concentrated stake can call into question the decentralization and neutrality of the network. In reality, these questions are vaguely answerable with data. But the overall integrity and safety of Ethereum PoS can only be ensured with no one entity surpassing critical stake thresholds. One entity controlling ⅓ of the stake can garner concern as it breaks Byzantine fault-tolerance: a critical property of the consensus protocol that ensures resilience against dishonest participants.

[21] The methodology used to identify Coinbase's deposits above capitalizes on a common passthrough pattern whereby funds are deposited into the staking contract from freshly-generated addresses which were funded from an address known to be Coinbase's. For example, in this transaction, Ethereum account 0x00c…f4D sends 32 ETH to the staking contract at 22:10:51 UTC. Tracing the funds back one hop we see that that address was funded only 10 minutes prior by the address 0xb5d…511, known to be associated with Coinbase.

ETHEREUM'S MACROECONOMICS: PRE & POST MERGE

Ethereum's macroeconomic policy is set to change dramatically with The Merge and transition to PoS. In this section, we explore the data behind the current ether issuance schedule under PoW, the economic dynamics of the PoS system, and model some potential outcomes post-Merge.

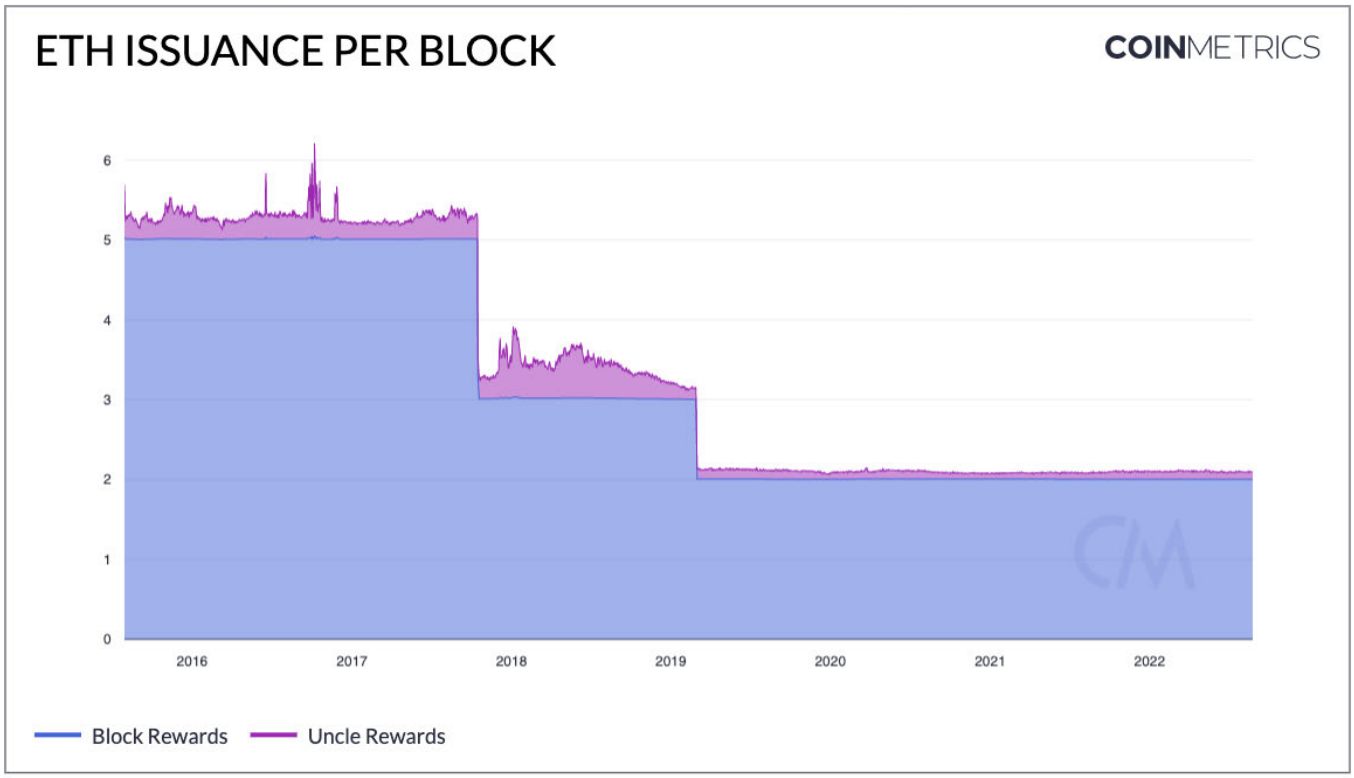


Artist: Viktor Hachmang

Current Economics (Pre-Merge)

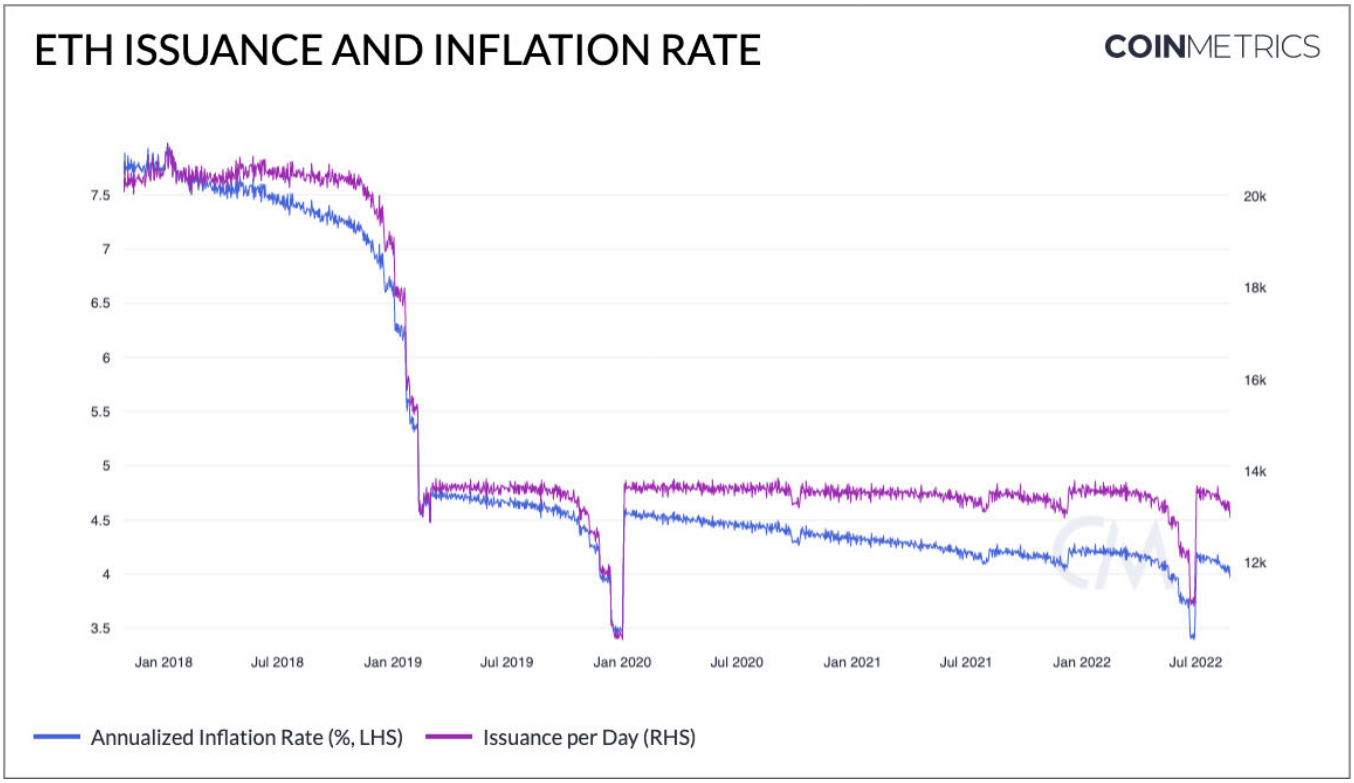
Currently, about 13.5K new ETH is issued each day. Miners receive newly issued ETH in the form of a block reward—which today is a flat 2 ETH rate—and uncle or ommer rewards as an added security measure that marginally increases issuance. With an average block time of 13.5 seconds, this implies 6,400 blocks per day where 2 ETH and any uncle rewards are paid out. On an annual basis this comes out to roughly 5M new ETH issued.

Ethereum's block reward is currently 2 ETH, but that was not always the case. Unlike many other proof-of-work blockchains Ethereum did not launch with a pre-set halving schedule. For example, Bitcoin's monetary policy has always dictated that every 210,000 blocks (roughly four years) the amount of BTC issued per block is cut in half. Compared to Bitcoin, ETH's macroeconomic policy has been far more malleable. ETH supply issuance has changed through hard forks over the years. The Ethereum block reward was originally 5 ETH, but was reduced to 3 ETH with the Byzantium hard fork in October 2017. Then in February 2019 block rewards were reduced once again from 3 ETH to 2 ETH as part of the Constantinople hard fork. The chart below shows the average per block issuance over time on Ethereum.



Source: Coin Metrics Network Data

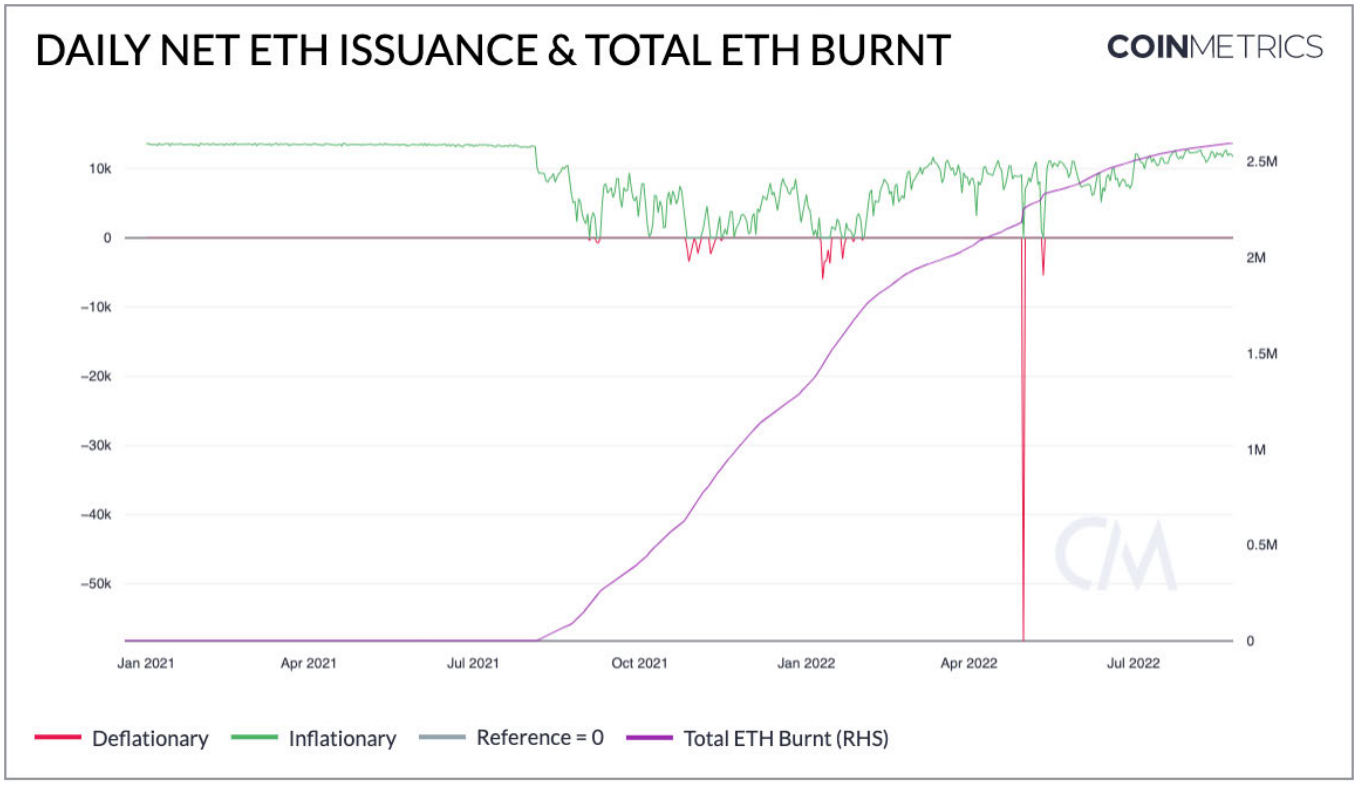
Miners are paid in the form of newly issued ETH which is a source of inflation in the ecosystem. At a rate of about 13.5K ETH per day, Ethereum's current annual inflation rate is slightly over 4%.



Source: Coin Metrics Network Data

However, Ethereum's macroeconomics were once again altered in August 2021 with the deployment of EIP-1559. Ethereum Improvement Proposal (EIP) 1559 introduced transaction fee burning as part of an overhaul to the transaction fee mechanism. In short, since EIP-1559, a majority of transaction fees are now "burned" and permanently removed from circulation. This burned ETH helps to reduce net supply issuance and therefore net inflation, since the supply that is being permanently removed from circulation offsets some of the newly issued block rewards. In addition to the burning mechanism, EIP-1559 also introduced the concept of priority fees or miner tips—as discussed earlier—which get paid to miners (validators post-Merge) and do not get burned. To see more data illustrating the impact of EIP-1559 check out our one-year retrospective research report here.

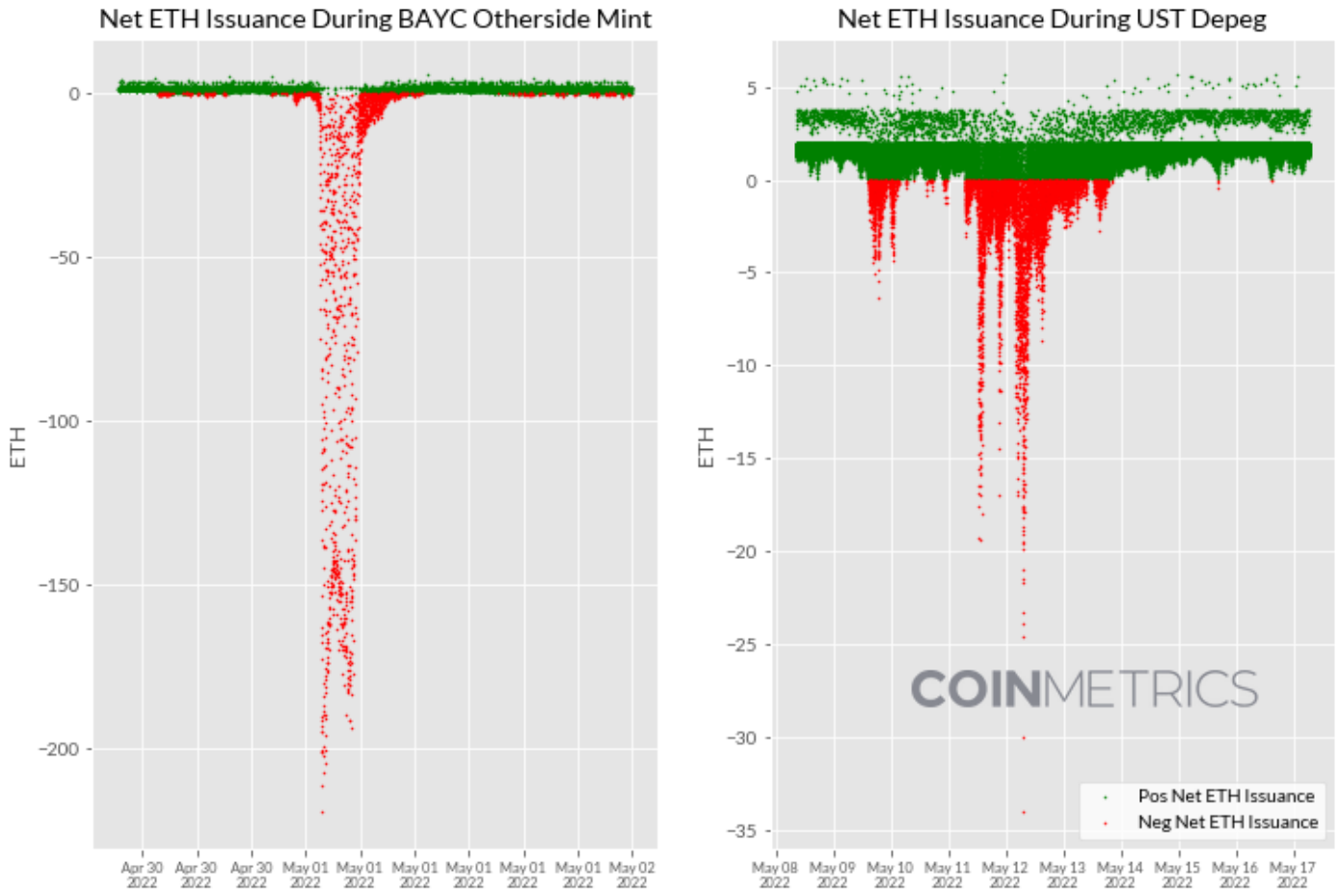
Taking into account the burning of base fees with EIP-1559, the net issuance of ETH can drop below zero at times, bringing periods of deflation during times of high fees.



Source: Coin Metrics Network Data

Since EIP-1559's launch over 2.6M ETH has been burnt. This has come out to about 6.7K ETH burnt every day. With a much higher 13.5K ETH issued daily on average under PoW, only 29 days were deflationary in the first year of EIP-1559.

Yet, the pockets of observed deflation pre-Merge have been especially pronounced during popular NFT mints or times of market volatility. The charts below show the per-block net ETH issuance during the May 2022 NFT 'Otherside' mint and collapse of Terra USD (UST).



Source: [Coin Metrics Network Data Pro]

The rate of fee burn on Ethereum has become a crucial variable in understanding ETH supply economics. No longer is ETH a monotonically-inflationary asset. However, the balance of burning and issuance is likely to tilt in favor of overall deflation with the adoption of PoS.

Future Economics (Post-Merge)

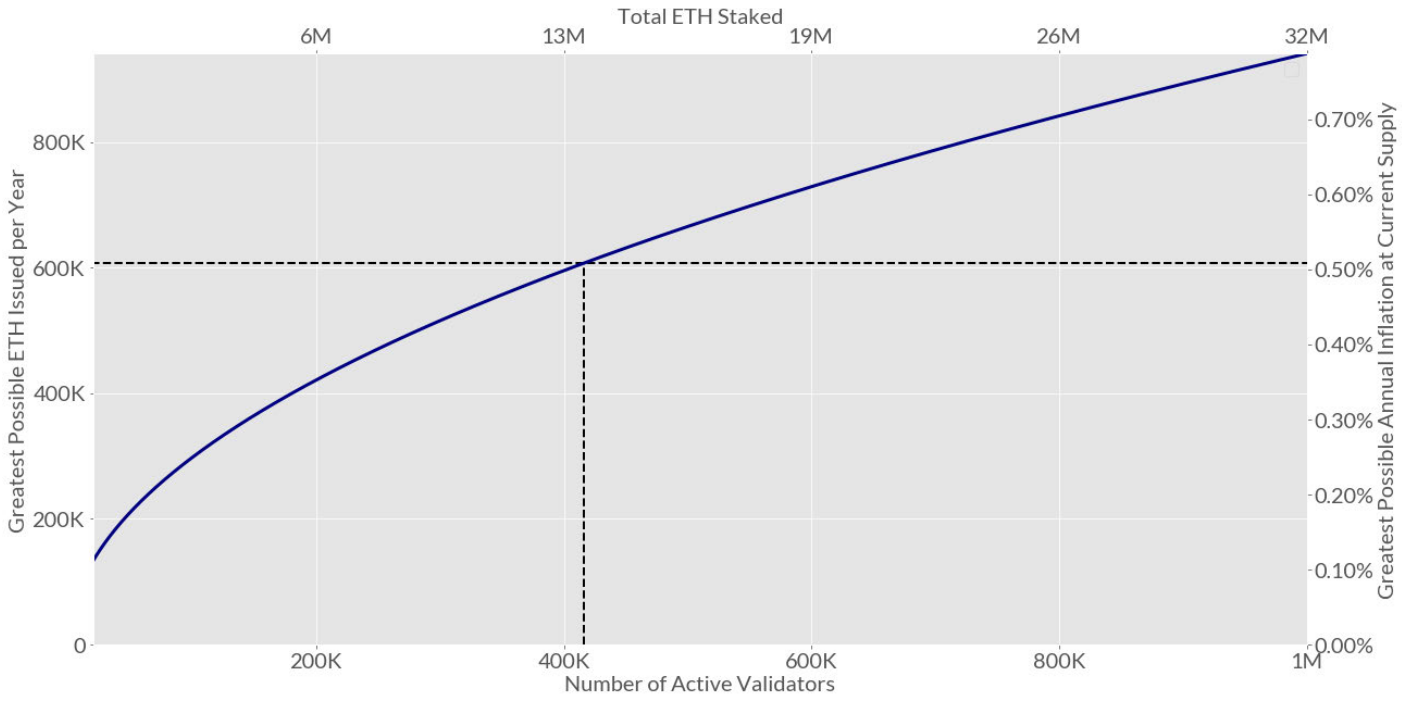
After The Merge, Ethereum will have a fundamentally different supply issuance schedule. Instead of issuing a flat rate of 2 new ETH per block (as well as uncle rewards) ETH's supply issuance schedule will dynamically change based on the total amount of ETH that is being staked.

Before the Beacon chain was launched, Ethereum developers set parameters for the maximum amount of annual issuance based on the total amount of ETH staked. The relationship between ETH issuance and ETH staked is simply the inverse of the rewards curve illustrated earlier. Put simply, as total ETH staked increases, total issuance increases, but at a decreasing rate.[22] With 13.3M ETH currently staked, this implies a maximum annual issuance of just over 600K ETH—an 88% reduction in yearly ETH issued compared to PoW today (note this is a maximum issuance because it assumes all validators will operate flawlessly).

Greatest ETH Issuance Scenario vs. Total ETH Staked

COINMETRICS

Source: Coin Metrics Labs



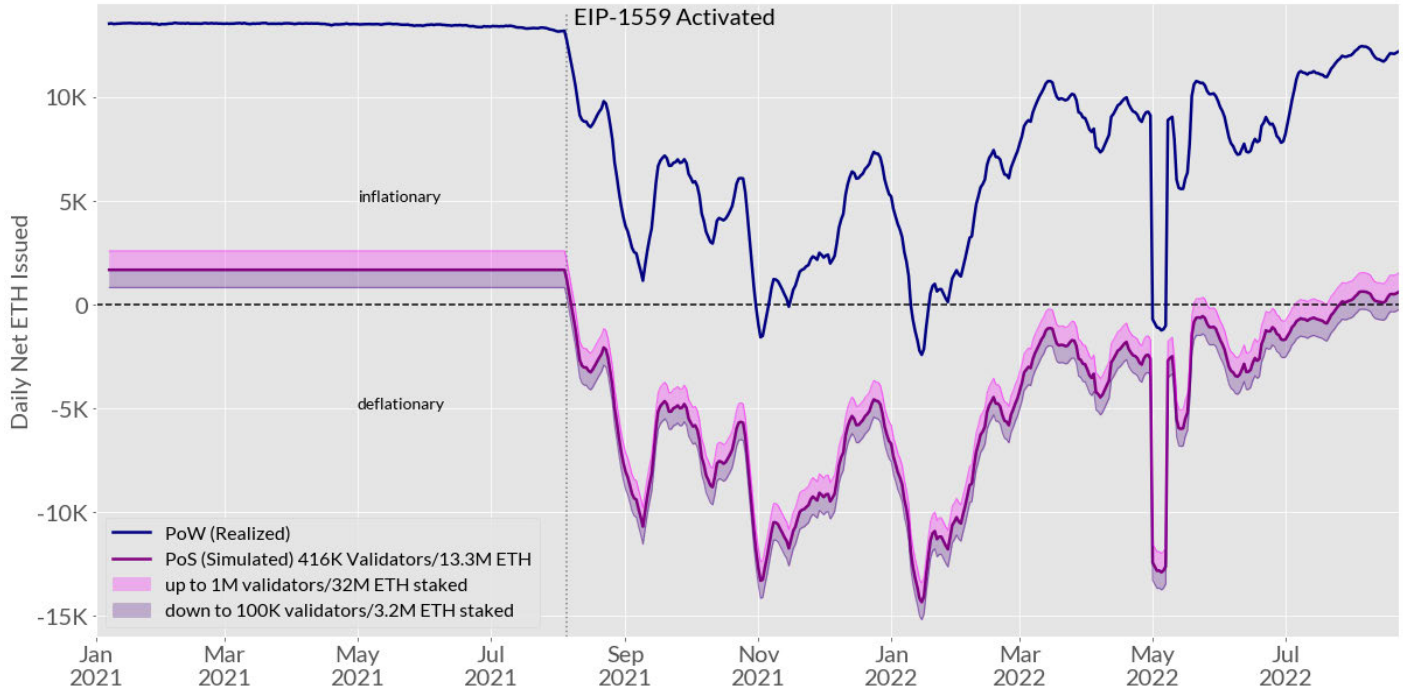
[22] The exact formula is the square root of total ETH staked.

A yearly issuance of 600K ETH implies a daily issuance rate of about 1.67K ETH. The average daily burn rate of 6.7K ETH found above far outpaces this daily issuance rate, implying frequent deflation. To better appreciate the impact of this stark reduction in issuance, the following chart simulates what daily ETH issuance would have looked like from January 2021 to today (pre-Merge), using a 1-week moving average of daily burn rate. Even under scenarios with up to 32M ETH staked, ETH would have been deflationary on almost every day since EIP-1559's launch under PoS.[23]

Daily Net ETH Issuance: PoW (Realized) vs. PoS (Simulated)

COINMETRICS

Source: Coin Metrics Labs

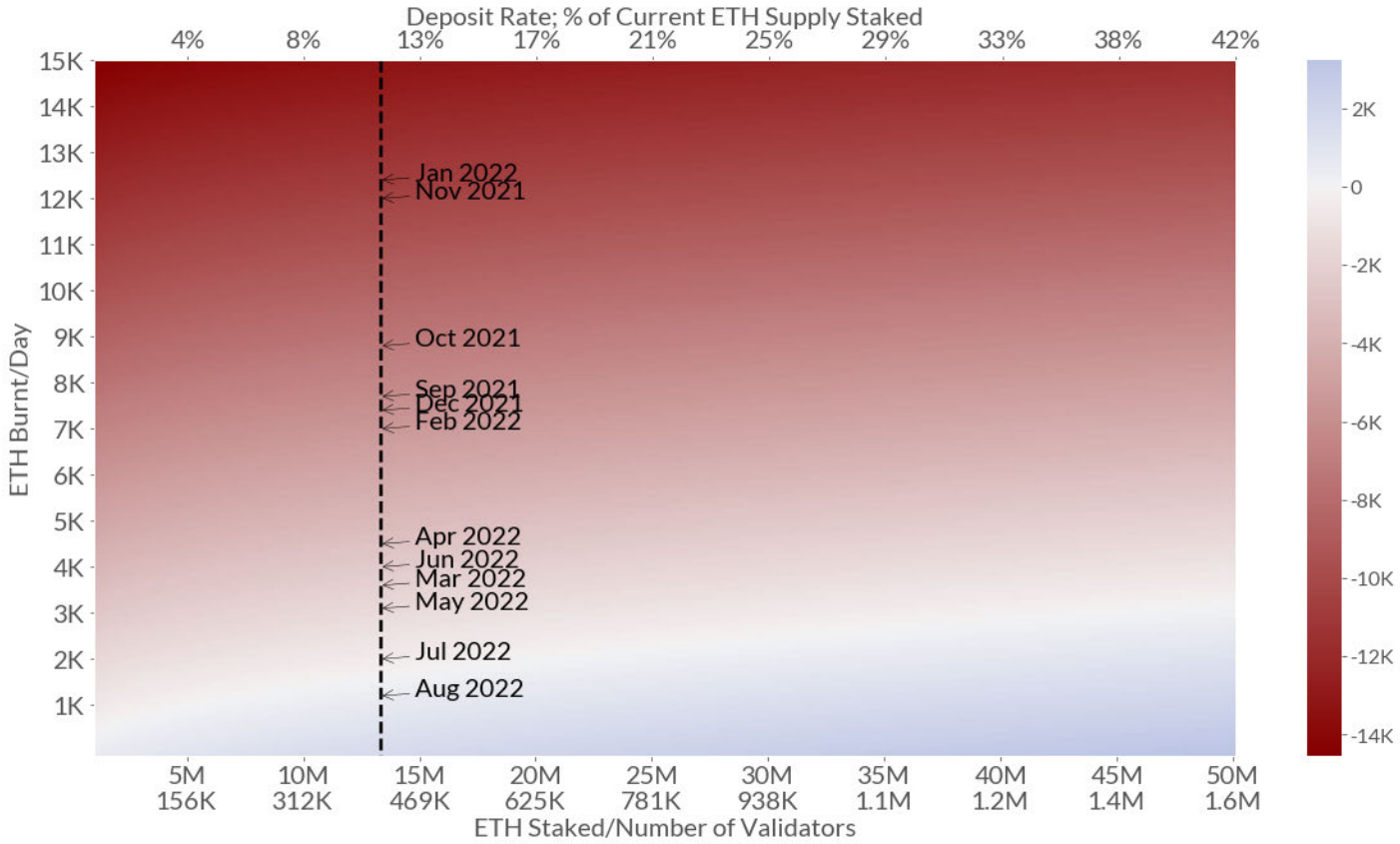


One can also see from the chart above that it is the burn rate—a byproduct of demand for Ethereum blockspace—rather than the amount of ETH staked, that chiefly determines net issuance. The burn rate has varied greatly since EIP-1559's launch. To account for the high variability of the burn rate, the heatmap below presents different scenarios of daily ETH burnt and ETH issued. The zone in blue represents an inflationary daily issuance, while the zone in red represents deflationary territory. The vertical dashed line shows the current amount of staked ETH with the dates corresponding to the median daily burn rate observed in that month.

[23] Note the above simulation does not count the ~740K ETH that was *actually* issued over the time frame on the consensus layer.

Simulated Daily Net ETH Issuance

Source: Coin Metrics Labs



In August 2022, tepid demand for Ethereum blockspace implies a slightly positive daily net issuance with 13.3M ETH staked. The base fee has averaged just around 13 GWEI (1 GWEI = 10^{-9} ETH) so far in August 2022. But if fees were to return to their January 2022 levels—averaging 132 GWEI—daily net ETH issuance would be negative with a high degree of confidence. As the number of validators increases, demand for blockspace must also increase in order for the system to beat issuance through the burning of more ETH.[24] As such, the health of PoS Ethereum as an economic system can be measured by looking at whether ETH burnt per day is above the "deflationary frontier" symbolized by the white line in the heat map.

[24] Note that a high deposit rate may imply a low propensity to transact on-chain, meaning that the burn rate may in fact *vary* with the amount of ETH staked. There has already been some promising economic modeling done that explores this very idea.

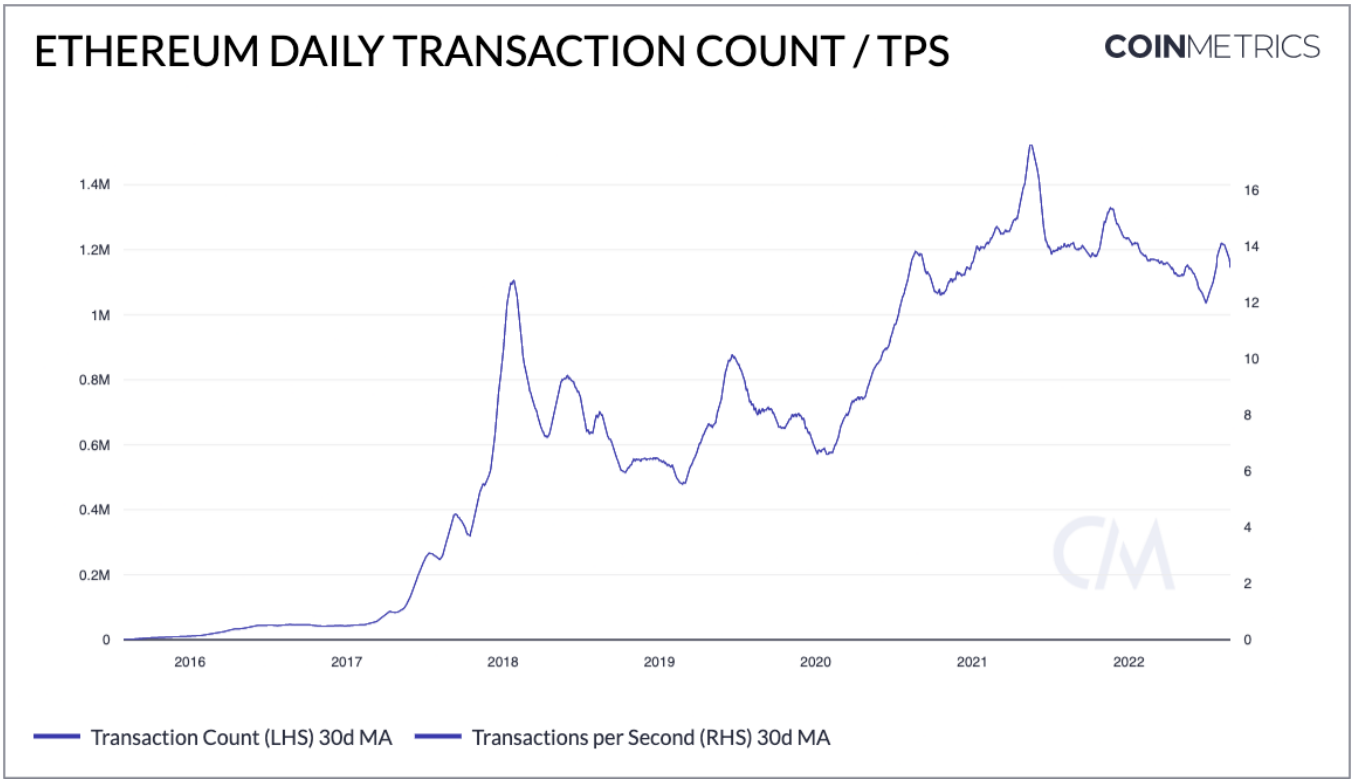
With so many unknown variables, it's tough to say exactly where ETH's circulating supply, today at roughly 120.28M (inclusive of 740K net ETH issued to date on the consensus layer), will settle after The Merge. Assuming all goes to plan, it might be reasonable to guess that the amount of staked ETH will increase after The Merge as the execution risk fades and validators start collecting tips and MEV. This would push total issuance up along the defined curve shown earlier.[25] If we remain in the current low-fee environment, total supply will continue to increase slightly, but only a small rise in fees will start pushing ETH supply downward. Considering this, it is very possible that ETH supply will peak right after The Merge before falling to a level years in the future where the issuance and burn rate reach an equilibrium. There is more modeling to be completed, but it's clear we're approaching a new monetary era for Ethereum.

THE MERGE AND THE FUTURE OF ETHEREUM

Ethereum's development roadmap extends far beyond The Merge, and while it is not set in stone, it helps provide context for the goals and intentions of The Merge. Ethereum developers have bucketed The Merge alongside a series of other long-term network upgrades, referred to (amusingly) today as The Surge, Purge, Verge, and Splurge. Below, we briefly give some intuition for each—beyond the clever rhymes. The overarching goal is to ultimately create a more robust version of Ethereum that can serve many millions of users and open the door for new types of applications. Importantly, these upgrades are being worked on simultaneously, but all assume a post-Merge era for Ethereum.

Ethereum's popularity over the last couple of years has served as a painful reminder that increased scalability is a pressing need for the network. At the base layer, Ethereum today handles about 1M transactions daily for a transaction per second rate of around 15. High demand for Ethereum has been a double-edged sword; network congestion often translates into expensive gas fees and prices-out some users. The ongoing development and adoption of layer-2 (L2) scaling solutions has helped, but the best outcomes will require network upgrades to amplify their effectiveness.

[25] Note there is a limit to how quickly new validators can enter and exit known as the activation and exit queue. This is put in place to ensure stability in the network's set of validators.



Source: Coin Metrics Network Data

This is the primary motivation behind the set of upgrades known as The Surge. The Surge plans to increase the scalability of Ethereum by introducing sharding. Sharding breaks up the network into smaller partitions that can operate in parallel, boosting overall throughput. The sharding roadmap is long and has evolved over time, but developers hope to first implement a technique that is being called Danksharding (named after Ethereum researcher Dankrad Feist), which is expected to improve the effectiveness of L2 rollup transactions. Suppose Ethereum is a final exam that you turn in to your professor. In that case, rollups are like the scratch paper used to help get to the final answer—only the original questions and answers are submitted and needed to check the solutions (kept on Ethereum L1), with the intermediate steps omitted. This helps keep costly data off the base layer while L2s inherit Ethereum's security assurances by regularly settling up on L1. The infrastructure of the Beacon Chain helps allow for sharding of these rollup transactions, which is likely to be the main way Ethereum attains greater scalability after The Merge.

If The Surge aims to increase Ethereum's throughput, The Purge aims to limit the amount of historical data that must be stored by validators, making it easier to run a node. Together with The Verge—which introduces a more efficient data structure known as the Verkle tree—the aim is to minimize the amount of historical data needed to be a validator.

The end goal is to create a "stateless Ethereum," where validators can validate blocks without storing the entire Ethereum chain. Instead, they rely on data availability proofs and pre-built blocks that maintain the set of validators unencumbered by computing requirements to promote validator decentralization and accessibility.

Then there is The Splurge, which captures all other miscellaneous upgrades that have been floated. One of the more interesting is the implementation of Proposal–Builder Separation, which is intended to reduce the impact of harmful MEV. After The Merge, validators retain the privilege to both build and propose blocks—but in the future, these duties could be separated, in order to more evenly distribute MEV rewards to all validators, including solo-stakers.

WHERE WILL THE MINERS GO?

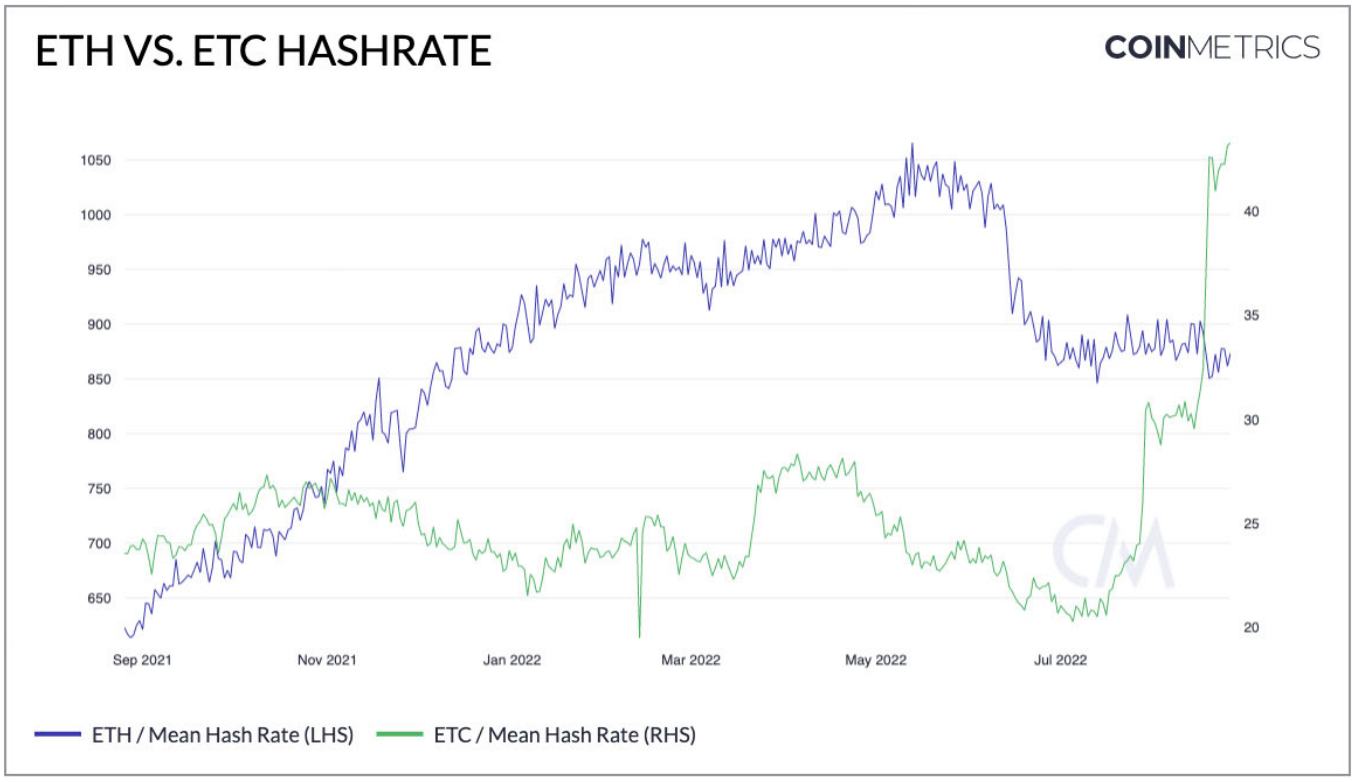
Lastly, as Ethereum miners start winding down, there is a lot of speculation around whether that hashrate (a proxy of PoW miners' computational output) will be directed to other networks. Following miners' next move is more than just a question of intrigue; the end of Ethereum mining marks the conclusion of an industry that received total revenue of $18.4B in 2021,[26] which topped all other PoW coins, even Bitcoin miners' $16.7B. It's a common misconception that Ethereum miners can simply redirect their hashrate to mining Bitcoin, but the two blockchains actually use two distinct, incompatible hashing algorithms. Bitcoin mining uses a standard cryptographic hashing function called Secure Hash Algorithm (SHA) SHA-256, while Ethereum introduced a custom, more complex algorithm known as Ethash.

In Bitcoin's early days, SHA-256 mining could be profitably performed on standard Graphics Processing Units (GPUs), high-performance circuits commonly used in gaming PCs and machine learning applications. As mining became more competitive, however, the industry increasingly shifted towards using Application Specific Integrated Circuits (ASICs). While GPUs are relatively versatile pieces of computer hardware utilized in a variety of software applications, ASICs are specialized mining hardware that are generally only compatible with a single hashing algorithm.

[26] About 25% from fees and 75% from block rewards (not counting MEV).

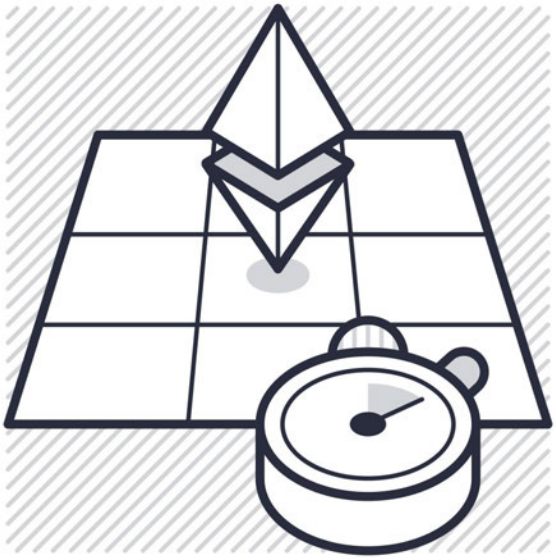
Ethereum's earliest developers viewed Bitcoin's trend towards ASIC mining as a dangerous centralization vector. In the words of the Ethereum whitepaper, ASICs meant that Bitcoin mining was "no longer a highly decentralized and egalitarian pursuit, requiring millions of dollars of capital to effectively participate in." As a result, the development team sought to embed their mining algorithm with "ASIC resistance." Several optimizations were introduced to ensure Ethereum mining had ASIC resistance, but the most important change was that miners were forced to use large amounts of Random Access Memory (RAM). Ultimately, this made mining far more difficult for ASICs, yet still friendly to GPUs.

As a result of this modification, mining enthusiasts can more rapidly enter and exit the ETH mining market, easily purchasing or liquidating hardware thanks to the diversity of broader GPU applications. A mature ASIC market doesn't exist for most smaller Proof-of-Work cryptocurrencies, and these devices are relatively challenging to trade compared to GPUs. Alternatively, Ethereum miners can shift their hashrate to mining ecosystems that depend on GPUs, the most notable being Ethereum's long-lost cousin Ethereum Classic (ETC), which arose from the chaos of the 2016 hack of The DAO. Indeed, over the past two months, Ethereum Classic's hashrate has nearly doubled. While the magnitude of hashrate allocated to ETC is substantially smaller than ETH, some speculate that the former will continue to absorb hashrate as ETH miners decide their next move.



Source: Coin Metrics Network Data

It is hard to speculate what will happen to the Ethereum mining ecosystem, given that a material source of their revenue is MEV. Although there are applications in ETC that can produce MEV opportunities, these pale in comparison to what ETH miners are used to obtaining. Compared to ETH, there is little-to-no DeFi activity on ETC today, no stablecoins, and magnitudes less liquidity. Even if a more lively ecosystem of applications develops on ETC, the tooling required for MEV in ETC, namely a Flashbots equivalent, does not currently exist. One possibility, of course, is an entirely new network to emerge via a fork of the Ethereum network where miners remain. Even in this scenario, however, it is difficult to see how this fork would retain current levels of hashrate given that the overwhelming majority of applications and users that finance the existing miners via fees will move to PoS Ethereum. Moreover, the importance and scale of stablecoins and other tokenized off-chain assets make an Ethereum hard fork intractable today.



CONCLUSION

As we have covered in this report, The Merge constitutes a significant shift for Ethereum. While most users might not see much difference in how they interact with Dapps post-Merge, the underlying system supporting these applications will have changed. After seven years in the making, miners will finally pass the symbolic block production torch to PoS validators, who will become the de-facto maintainers of Ethereum. This is perhaps the most significant economic shift in the history of crypto assets and it should be fascinating to see its impact on-chain.

To contextualize this shift, we will continue to monitor trends in the set of validators maintaining the Ethereum network. We expect Liquid Staking Derivatives to play a big role in the dynamics of PoS and it should be interesting to monitor their usage, especially as a new collateral type in DeFi. As a centralization factor, these products must be used carefully so they don't undermine the core economics of PoS. We plan on covering this trend in future reports, as we predict most exchanges will enter the staking derivatives market.

It has been a long journey for Coin Metrics to support The Merge. We have actively been running nodes for the Beacon Chain ever since its launch in late 2020. Although there have been substantial improvements in the stability of the clients that will support PoS Ethereum, we must also acknowledge that a lot can go wrong in a network migration of this magnitude. For example, in the Goerli "mock Merge," our nodes saw the transition occur twice, which could have been disruptive to uptime had it been the actual Merge.

Given the scope of factors that can hurt Ethereum's uptime during the Merge, it might be prudent to refrain from transacting that day. In the event a reorg (change in block ordering) happens, a large set of transactions might be sent back to the mempool and get stuck. This could entail large disruptions in the network. Even if things go perfectly well with the activation mechanism, any delay will entail pricing discrepancies in DeFi DEXs and lending markets. While these may generate generous payouts in MEV, they could also negatively impact regular users.

Despite these potential risks, we look forward to evaluating the economics and security of Ethereum post-Merge with new metrics and insights. The Merge will enable a host of exciting new scalability solutions to be more easily implemented in Ethereum. This report marks the beginning of a new coverage universe for us at Coin Metrics.

MAPPING OUT THE MERGE

UNDERSTANDING ETHEREUM'S MOVE TO PROOF OF STAKE

By Kyle Waters, Lucas Nuzzi, Nate Maddrey, Matías Andrade, and the Coin Metrics Team

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