

How The Merge impacted ETH supply {#how-the-merge-impacts-ETH-supply}

The Merge represented the Ethereum network's transition from proof-of-work to proof-of-stake which occurred in September 2022. The way ETH was issued underwent changes at time of that transition. Previously, new ETH was issued from two sources: the execution layer (i.e. Mainnet) and the consensus layer (i.e. Beacon Chain). Since The Merge, issuance on the execution layer is now zero. Let's break this down.

Components of ETH issuance {#components-of-eth-issuance}

We can break the supply of ETH into two primary forces: issuance and burn.

The **issuance** of ETH is the process of creating ETH that did not previously exist. The **burning** of ETH is when existing ETH gets destroyed, removing it from circulation. The rate of issuance and burning gets calculated on several parameters, and the balance between them determines the resulting inflation/deflation rate of ether.

- Before transitioning to proof-of-stake, miners were issued approximately 13,000 ETH/day
- Stakers are issued approximately 1,700 ETH/day, based on about 14 million total ETH staked
- The exact staking issuance fluctuates based on the total amount of ETH staked
- **Since The Merge, only the ~1,700 ETH/day remains, dropping total new ETH issuance by ~88%**
- The burn: This fluctuates according to network demand. *If* an average gas price of at least 16 gwei is observed for a given day, this effectively offsets the ~1,700 ETH that is issued to validators and brings net ETH inflation to zero or less for that day.

Pre-merge (historical) {#pre-merge}

Execution layer issuance {#el-issuance-pre-merge}

Under proof-of-work, miners only interacted with the execution layer and were rewarded with block rewards if they were the first miner to solve the next block. Since the [Constantinople upgrade](#) in 2019 this reward was 2 ETH per block. Miners were also rewarded for publishing [ommer](#) blocks, which were valid blocks that didn't end up in the longest/canonical chain. These rewards maxed out at 1.75 ETH per ommer, and were *in addition to* the reward issued from the canonical block. The process of mining was an economically intensive activity, which historically required high levels of ETH issuance to sustain.

Consensus layer issuance {#cl-issuance-pre-merge}

The [Beacon Chain](#) went live in 2020. Instead of miners, it is secured by validators using proof-of-stake. This chain was bootstrapped by Ethereum users depositing ETH one-way into a smart contract on Mainnet (the execution layer), which the Beacon Chain listens to, crediting the user with an equal amount of ETH on the new chain. Until The Merge happened, the Beacon Chain's validators were not processing transactions and were essentially coming to consensus on the state of the validator pool itself.

Validators on the Beacon Chain are rewarded with ETH for attesting to the state of the chain and proposing blocks. Rewards (or penalties) are calculated and distributed at each epoch (every 6.4 minutes) based on validator performance. Validator rewards are **significantly** less than the mining rewards that were previously issued under proof-of-work (2 ETH every ~13.5 seconds), as operating a validating node is not as economically intense and thus does not require or warrant as high a reward.

Pre-merge issuance breakdown {#pre-merge-issuance-breakdown}

Total ETH supply: ~**120,520,000 ETH** (at time of The Merge in September 2022)

Execution layer issuance:

- Was estimated at 2.08 ETH per 13.3 seconds*:~**4,930,000** ETH issued in a year
- Resulted in an inflation rate of **approximately 4.09%** (4.93M per year / 120.5M total)
- *This includes the 2 ETH per canonical block, plus an average of 0.08 ETH over time from ommer blocks. Also uses 13.3 seconds, the baseline block time target without any influence from a [difficulty bomb](#). ([See source](#))

Consensus layer issuance:

- Using 14,000,000 total ETH staked, the rate of ETH issuance is approximately 1700 ETH/day ([See source](#))
- Results in ~**620,500** ETH issued in a year
- Resulted in inflation rate of **approximately 0.52%** (620.5K per year / 119.3M total)

Total annualized issuance rate (pre-merge): ~4.61% (4.09% + 0.52%)

~**88.7%** of the issuance was going to miners on the execution layer (4.09 / 4.61 * 100)

~**11.3%** was being issued to stakers on the consensus layer (0.52 / 4.61 * 100)

Post-merge (present day) {#post-merge}

Execution layer issuance {#el-issuance-post-merge}

Execution layer issuance since The Merge is zero. Proof-of-work is no longer a valid means of block production under the upgraded rules of consensus. All execution layer activity is packaged into "beacon blocks", which are published and attested to by proof-of-stake validators. Rewards for attesting-to and publishing beacon blocks are accounted for separately on the consensus layer.

Consensus layer issuance {#cl-issuance-post-merge}

Consensus layer issuance continues today as before The Merge, with small rewards for validators who attest to and propose blocks. Validator rewards continue to accrue to *validator balances* that are managed within the consensus layer. Unlike the current accounts ("execution" accounts), which can transact on Mainnet, these are separate Ethereum accounts cannot transact freely with other Ethereum accounts. Funds in these accounts can only be withdrawn to a single specified execution address.

Since the Shanghai/Capella upgrade that took place in April 2023, these withdrawals have been enabled for stakers. Stakers are incentivized to remove their *earnings/rewards (balance over 32 ETH)* as these funds are otherwise not contributing to their stake weight (which maxes at 32).

Stakers may also choose to exit and withdraw their entire validator balance. To ensure Ethereum is stable, the number of validators leaving simultaneously is capped.

Approximately 0.33% of the total validator count may exit in a given day. By default, four (4) validators may exit per epoch (every 6.4 minutes, or 900 per day). An additional one (1) validator is permitted to exit for every 65,536 (2^{16}) additional validators over 262,144 (2^{18}). For example, with over 327,680 validators, five (5) may leave per epoch (1,125 per day). Six (6) will be permitted with a total active validator count over 393,216, and so forth.

As more validators withdraw, the maximum number of exiting validators will gradually be reduced to a minimum of four to intentionally prevent large destabilizing amounts of staked ETH from being withdrawn concurrently.

Post-merge inflation breakdown {#post-merge-inflation-breakdown}

- Total ETH supply: ~**120,520,000 ETH** (at time of The Merge in September 2022)
- Execution layer issuance: **0**
- Consensus layer issuance: Same as above, ~**0.52%** annualized issuance rate (with 14 million total ETH staked)

Total annualized issuance rate: ~**0.52%**

Net reduction in annual ETH issuance: ~88.7% $((4.61\% - 0.52\%) / 4.61\% * 100)$

The burn {#the-burn}

The opposite force to ETH issuance is the rate at which ETH is burned. For a transaction to execute on Ethereum, a minimum fee (known as a "base fee") must be paid, which fluctuates continuously (block-to-block) depending on network activity. The fee is paid in ETH and is *required* for the transaction to be considered valid. This fee gets *burned* during the transaction process, removing it from circulation.

Fee burning went live with [the London upgrade](#) in August 2021, and remains unchanged since The Merge.

On top of the fee burn implemented by the London upgrade, validators can also incur penalties for being offline, or worse, they can be slashed for breaking specific rules that threaten network security. These penalties result in a reduction of ETH from that validator's balance, which is not directly rewarded to any other account, effectively burning/removing it from circulation.

Calculating average gas price for deflation {#calculating-average-gas-price-for-deflation}

As discussed above, the amount of ETH issued in a given day is dependent upon the total ETH staked. At time of writing, this is approximately 1700 ETH/day.

To determine the average gas price required to completely offset this issuance in a given 24-hour period, we'll start by calculating the total number of blocks in a day, given a block time of 12 seconds:

- $(1 \text{ block} / 12 \text{ seconds}) * (60 \text{ seconds/minute}) = 5 \text{ blocks/minute}$
- $(5 \text{ blocks/minute}) * (60 \text{ minutes/hour}) = 300 \text{ blocks/hour}$
- $(300 \text{ blocks/hour}) * (24 \text{ hours/day}) = 7200 \text{ blocks/day}$

Each block targets 15×10^6 gas/block ([more on gas](#)). Using this, we can solve for the average gas price (in units of gwei/gas) required to offset issuance, given a total daily ETH issuance of 1700 ETH:

- $7200 \text{ blocks/day} * 15 \times 10^6 \text{ gas/block} * Y \text{ gwei/gas} * 1 \text{ ETH} / 10^9 \text{ gwei} = 1700 \text{ ETH/day}$

Solving for Y :

- $Y = (1700(10^9)) / (7200 * 15(10^6)) = (17 \times 10^3) / (72 * 15) = 16 \text{ gwei}$ (rounding to only two significant digits)

Another way to rearrange this last step would be to replace 1700 with a variable x that represents the daily ETH issuance, and to simplify the rest to:

- $Y = (x(10^3) / (7200 * 15)) = x/108$

We can simplify and write this as a function of x :

- $f(x) = x/108$ where x is daily ETH issuance, and $f(x)$ represents the gwei/gas price required to offset all of the newly issued ETH.

So, for example, if x (daily ETH issuance) rises to 1800 based on total ETH staked, $f(x)$ (gwei required to offset all of the issuance) would then be 17 gwei (using 2 significant digits)

Further reading {#further-reading}

- [The Merge](#)
- [Ultrasound.money](#) - Dashboards available to visualize ETH issuance and burn in real-time
- [Charting Ethereum Issuance](#) - Jim McDonald 2020