21 Keys to Ethereum Blockchain

Master the essentials of Ethereum Blockchain.

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Beacon Chain

The proof-of-stake consensus layer of Ethereum, coordinating validators since December 2020.

The Beacon Chain is Ethereum's proof-of-stake (PoS) blockchain, launched on December 1, 2020, to manage the PoS consensus mechanism. It operates as the coordination layer for validators who stake ETH to secure the network, propose blocks, and attest to their validity.

Fully integrated with Ethereum's execution layer during The Merge in 2022, the Beacon Chain replaced proof-of-work mining, enabling faster and more energy-efficient transaction processing. It is critical for Ethereum's security and scalability, supporting validator duties and finality.

Blockchain Trilemma

The blockchain trilemma refers to the challenge of balancing three core properties—decentralization, security, and scalability—in a blockchain network, where optimizing one often compromises the others.

The blockchain trilemma, a concept popularized by Ethereum co-founder Vitalik Buterin, describes the trade-offs blockchain networks face in achieving three desirable attributes: decentralization, security, and scalability.

Decentralization ensures no single entity controls the network, fostering trust and censorship resistance. Security protects the network from attacks, ensuring data integrity and user funds. Scalability enables the network to handle high transaction volumes efficiently. The trilemma posits that improving one of these aspects typically weakens at least one of the others, creating a delicate balance for blockchain designers.

For example, Bitcoin prioritizes decentralization and security, with a distributed network of nodes and robust cryptographic mechanisms like proof-of-work (PoW). However, its scalability is limited, processing only about 4-7 transactions per second (TPS). Ethereum, similarly, has faced scalability challenges, though layer-2 solutions like Optimism and Arbitrum aim to address this while maintaining decentralization and security. In contrast, some newer blockchains, like Solana, achieve high scalability (up to 65,000 TPS) but face criticism for potential centralization due to high hardware requirements for validators, which can reduce node diversity.

Solutions to the trilemma include Rollups (e.g., Ethereum's roadmap), layer-2 scaling (e.g., Lightning Network for Bitcoin), or alternative consensus mechanisms like proof-of-stake (PoS),

which reduce energy costs but introduce new trade-offs. No blockchain has fully "solved" the trilemma, and projects must align their design choices with their intended use case, such as prioritizing scalability for payments or decentralization for governance.

EIP-1559

An Ethereum upgrade that introduced a dynamic base fee for transactions, implemented in August 2021.

EIP-1559 (Ethereum Improvement Proposal 1559), activated on August 5, 2021, reformed Ethereum's transaction fee market. It introduced a base fee, automatically adjusted based on network demand, which is burned (removed from circulation) to reduce ETH supply inflation. Users can add a priority fee to incentivize faster transaction inclusion. EIP-1559 improves fee predictability, reduces overpayment, and supports Ethereum's economic sustainability. It also dynamically adjusts the block gas limit to manage congestion, enhancing user experience.

EIP (Ethereum Improvement Proposal)

A standardized process for proposing and implementing changes to the Ethereum protocol.

An Ethereum Improvement Proposal (EIP) is a formal document outlining proposed changes, enhancements, or standards for the Ethereum ecosystem.

EIPs cover protocol upgrades, smart contract standards (e.g., ERC-20, ERC-721), and network improvements (e.g., EIP-1559).

Submitted by developers or community members, EIPs undergo rigorous review, discussion, and consensus-building via GitHub and Ethereum forums. Once approved, they guide implementation, ensuring Ethereum evolves transparently and collaboratively to address scalability, security, or functionality needs.

Epoch of Ethereum PoS

A fixed period in Ethereum's proof-of-stake consensus, typically 32 slots, used for validator duties and finality.

In Ethereum's proof-of-stake (PoS) consensus mechanism, introduced after The Merge in 2022, an epoch is a time period consisting of 32 slots, each lasting 12 seconds, totaling approximately 6.4 minutes. During an epoch, validators are assigned duties such as proposing blocks or attesting to the validity of blocks to secure the network. Epochs are critical for finalizing blockchain states, as they determine when a sufficient number of attestations are collected to mark a portion of the chain as "finalized," ensuring its immutability. This structure supports Ethereum's scalability and security.

Ethereum (ETH)

A decentralized blockchain platform that pioneered smart contracts, enabling programmable money and decentralized applications.

Ethereum is a blockchain network, launched in 2015 by Vitalik Buterin and co-founders, that pioneered the smart contract platform. With Ether (ETH) as its native cryptocurrency, Ethereum serves as the world's settlement layer, acting as critical financial infrastructure akin to Google's role in information technology. It powers decentralized applications (dApps), decentralized finance (DeFi), non-fungible tokens (NFTs), decentralized autonomous organizations (DAOs), as well as real-world assets(RWAs). As the second-largest digital asset by market cap, ETH facilitates transactions, staking, and yield generation. Its consensus algorithm was transformed from PoW to PoS in 2022 to enhance scalability, energy efficiency, and throughput.

Over $165 billion in stablecoins is currently on the Ethereum network underscoring its role in liquidity and DeFi ecosystems.

Ethereum Contract Account

A blockchain account containing smart contract code, controlled by its programmed logic rather than a private key.

A Contract Account is an Ethereum account that contains smart contract code and is controlled by its programmed logic, not a private key.

Created when a smart contract is deployed to the blockchain, it has a unique address and can hold Ether or tokens. Contract accounts execute their code automatically when triggered by a transaction from an EOA or another contract, enabling functionalities like automated token transfers or complex dApp logic. They are fundamental to Ethereum's programmable ecosystem.

Ethereum EOA Account

An externally owned account on Ethereum, controlled by a private key and used to initiate transactions.

An Externally Owned Account (EOA) is one of the two types of accounts on the Ethereum blockchain, controlled by a user via a private key. EOAs are associated with a public address and can hold Ether (ETH) or tokens, as well as initiate transactions, such as sending ETH or interacting with smart contracts.

Unlike contract accounts, EOAs do not contain executable code and rely on user-initiated actions. Wallets like MetaMask typically manage EOAs, allowing users to sign transactions securely.

Ethereum Node

A software client that participates in Ethereum's Proof-of-Stake network to validate, store, or relay blockchain data.

An Ethereum node in the context of Proof-of-Stake (PoS) is a computer running software that connects to the Ethereum network to perform tasks such as validating transactions, storing the blockchain's state, or relaying data. Since Ethereum's transition to PoS with The Merge in 2022, nodes are categorized into execution clients (handling transaction processing and smart contract execution) and consensus clients (managing the PoS consensus mechanism). Common execution clients include Geth, Nethermind, and Besu, while consensus clients include Lighthouse, Prysm, and Teku. Nodes can operate as full nodes, which store the entire blockchain, or light nodes, which store minimal data for faster operation.

In PoS, validator nodes play a critical role by staking a minimum of 32 ETH to propose and attest to new blocks. Running a validator node requires both an execution client and a consensus client, synchronized with the network, and constant uptime to avoid penalties. Non-validating nodes, such as full or light nodes, support the network by storing data or facilitating transactions without staking. As of 2025, over 1 million validators are active, per beaconcha.in, ensuring Ethereum's decentralization and security. Operating a node requires technical expertise, reliable hardware, and stable internet, but it contributes to Ethereum's resilience and transparency.

Staking of Ethereum PoS

The process of locking up Ether (ETH) to participate in Ethereum's Proof-of-Stake consensus and earn rewards.

Staking in Ethereum's Proof-of-Stake (PoS) system, implemented after The Merge in 2022, involves locking up a minimum of 32 ETH in a validator smart contract to help secure the Ethereum network.

Stakers, or validators, are responsible for proposing and attesting to new blocks in the blockchain, ensuring transaction validity and network consensus. In return, they earn rewards in the form of newly issued ETH and transaction fees, typically yielding 2-5% annual percentage return (APR) as of 2025.

To stake, users run a validator node using an execution client (e.g., Geth, Besu) and a consensus client (e.g., Lighthouse, Prysm), requiring reliable hardware and internet to avoid penalties like slashing, where a portion of staked ETH is lost for malicious or negligent behavior.

Staking can be done solo, requiring technical expertise, or through staking pools (e.g., Lido, Rocket Pool) for those with less than 32 ETH or limited technical skills, though pools introduce third-party risks. Over 1 million validators are active as of 2025, with more than 33 million ETH staked, representing over 25% of Ethereum's total supply, per beaconcha.in, enhancing network security and decentralization.

Restaking (Ethereum PoS)

Restaking on Ethereum's Proof-of-Stake (PoS) enables staked ETH to secure additional protocols via EigenCloud (previously EigenLayer), earning extra rewards while extending Ethereum's cryptoeconomic security.

Restaking, pioneered by EigenCloud (formerly EigenLayer), allows Ethereum validators and liquid staking token (LST) holders to reuse their staked ETH to provide security for other decentralized services, known as Actively Validated Services (AVSs). Launc

hed in 2023 on Ethereum's mainnet, EigenCloud operates as a middleware protocol where users deposit native staked ETH (minimum 32 ETH per validator) or LSTs like stETH into smart contracts, delegating them to operators who run AVS nodes. This extends Ethereum's $33+ billion in staked ETH to secure rollups, oracles, bridges, and data availability layers, reducing bootstrap costs for new protocols from millions in validator setup to renting Ethereum's pooled security.

Users earn compounded yields—base Ethereum staking APR of ~3.2% plus AVS-specific rewards in ETH, EIGEN tokens, or ERC-20s—potentially reaching 5-8% total, according to EigenCloud data and DeFiLlama TVL metrics showing $17.51 billion restaked As of 2025.

EVM (Ethereum Virtual Machine)

A decentralized computation engine that executes smart contracts on the Ethereum blockchain.

The Ethereum Virtual Machine (EVM) is a Turing-complete virtual machine embedded in every Ethereum node, responsible for executing smart contract code.

It provides a sandboxed environment where smart contracts, written in languages like Solidity, are compiled into bytecode and run deterministically across the network. The EVM ensures that all nodes reach the same state after executing a contract, enabling trustless and decentralized computation. Gas fees, paid in ETH, limit the computational resources used by the EVM to prevent abuse and ensure network efficiency.

Gas (Ethereum)

A unit measuring the computational effort required to execute transactions or smart contracts on Ethereum.

Gas is a unit that quantifies the computational work needed to process transactions or execute smart contracts on the Ethereum blockchain. Each operation in the Ethereum Virtual Machine (EVM), such as transferring ETH or running a smart contract, consumes a specific amount of gas. Users pay for gas in Ether (ETH), with the total cost determined by the gas limit (the maximum gas a transaction can use) and the gas price (the amount of ETH per gas unit). Gas ensures network resources are allocated efficiently and prevents spam or infinite loops.

Gas Limit of a Block

The maximum total gas allowed for all transactions included in an Ethereum block.

The block gas limit on Ethereum caps the total gas that all transactions in a single block can consume, controlling the computational load on the network. As of 2025, Ethereum's block gas limit is approximately 30 million gas, adjusted dynamically by validators under EIP-1559 rules to manage network congestion. This limit ensures blocks are processed efficiently within the 12-second slot time, balancing throughput and decentralization. Exceeding the block gas limit prevents a block from being valid, maintaining network stability.

Gas Limit of a Transaction

The maximum amount of gas a user is willing to spend on an Ethereum transaction.

The gas limit for a transaction on Ethereum specifies the maximum computational effort, measured in gas units, that a user is willing to allocate for executing a transaction or smart contract. It ensures transactions don't consume excessive network resources. For example, a simple ETH transfer might require 21,000 gas, while complex smart contract interactions need more. If the gas limit is too low, the transaction fails; if too high, unused gas is refunded. Users set this limit in wallets like MetaMask, balancing cost and reliability.

Gas Price

The amount of Ether (ETH) a user is willing to pay per unit of gas for a transaction on Ethereum.

Gas price is the cost per unit of gas, denominated in Gwei (1 Gwei = 10^-9 ETH), that a user sets when submitting a transaction to the Ethereum network. It determines the priority of the transaction, as validators typically prioritize transactions with higher gas prices. After EIP-1559 (implemented in August 2021), the gas price consists of a base fee (burned by the network) and an optional priority fee (paid to validators). Users can adjust gas prices in wallets like MetaMask to balance speed and cost.

Proof-of-Work (PoW) Ethereum

A consensus mechanism formerly used by Ethereum to secure its network and validate transactions through computational work.

Proof-of-Work (PoW) was the original consensus mechanism for Ethereum from its launch in 2015 until *The Merge* in 2022, when Ethereum transitioned to Proof-of-Stake (PoS). In PoW, miners competed to solve complex mathematical puzzles using computational power to validate transactions and create new blocks. The first miner to solve the puzzle earned the right to add a block to the blockchain and received rewards in Ether (ETH) along with transaction fees. This process secured the network but required significant energy consumption, with Ethereum's PoW consuming an estimated 70-80 TWh annually before the transition, comparable to the energy use of a small country.

Ethereum's PoW relied on the Ethash algorithm, designed to be ASIC-resistant and favor GPU mining to promote decentralization. However, it faced challenges like high energy costs and environmental concerns, which prompted the shift to PoS. While PoW was critical in establishing Ethereum's early security and decentralization, its inefficiencies led to its replacement, making it obsolete for Ethereum's mainnet but still relevant for understanding Ethereum's history and some Ethereum-based forks like Ethereum Classic.

Proof-of-Stake (PoS) Ethereum

A consensus mechanism used by Ethereum to secure its network and validate transactions.

Proof-of-Stake (PoS) is the consensus mechanism implemented by Ethereum following *The Merge* in 2022, transitioning the network from Proof-of-Work (PoW) to PoS. In PoS, validators are chosen to create new blocks and confirm transactions based on the amount of Ether (ETH) they stake as collateral, rather than competing through computational power as in PoW. Validators lock up a minimum of 32 ETH in a staking contract to participate, and they are incentivized to act honestly through rewards and penalties, with the risk of losing their stake (slashing) for malicious behavior.

Ethereum's PoS, specifically its *Casper* implementation, enhances energy efficiency, reducing the network's energy consumption by approximately 99.95% compared to PoW, according to Ethereum Foundation estimates. It also aims to improve scalability and security while enabling features like sharding for future upgrades. Validators propose and attest to blocks in fixed time intervals called slots (12 seconds), grouped into epochs (32 slots, or ~6.4 minutes). The mechanism balances decentralization, as anyone with sufficient ETH can stake, with economic incentives to maintain network integrity.

The Merge

Ethereum's transition from proof-of-work to proof-of-stake consensus, completed on September 15, 2022.

The Merge was a major upgrade to Ethereum, finalized on September 15, 2022, marking the shift from energy-intensive proof-of-work (PoW) to proof-of-stake (PoS) consensus. It integrated Ethereum's original execution layer with the Beacon Chain, a PoS-based consensus layer introduced in December 2020. The Merge reduced Ethereum's energy consumption by ~99.95%, improved scalability potential, and set the stage for future upgrades like sharding. It did not directly lower transaction fees but enabled mechanisms like EIP-1559 to optimize fee dynamics.

Turing Complete (Ethereum)

The ability of Ethereum's programming environment to compute any function given sufficient resources.

Ethereum is considered Turing complete because its Ethereum Virtual Machine (EVM) and programming languages like Solidity can theoretically compute any function or algorithm, provided enough computational resources (gas) are available. This property allows developers to create complex smart contracts and decentralized applications with diverse functionalities, such as loops and conditional logic. However, gas limits prevent infinite computations, ensuring network efficiency. Turing completeness distinguishes Ethereum from more limited blockchains, enabling its robust ecosystem of dApps and programmable finance.

Validator of PoS

Network participants staking tokens to propose and attest blocks in proof-of-stake consensus.

In PoS, validators stake 32 ETH ($130,000 at $4,000/ETH) to run nodes, proposing blocks every 12 seconds and attesting via committees—Ethereum's 1 million validators secure $400 billion. Selection is pseudorandom, weighted by stake, slashing 1-100% for downtime/malice.

Solana validators (2,000+) stake SOL for 1,500 TPS, earning 6% APY minus 8% commission, requiring 128 GB RAM setups. Cardano's Ouroboros selects via stake pools, processing 250 TPS.

Energy-efficient (99% less than PoW), PoS validators earn $10 billion yearly rewards, but centralization risks (top 1% control 33% stake) prompt delegation tools.

ETH

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