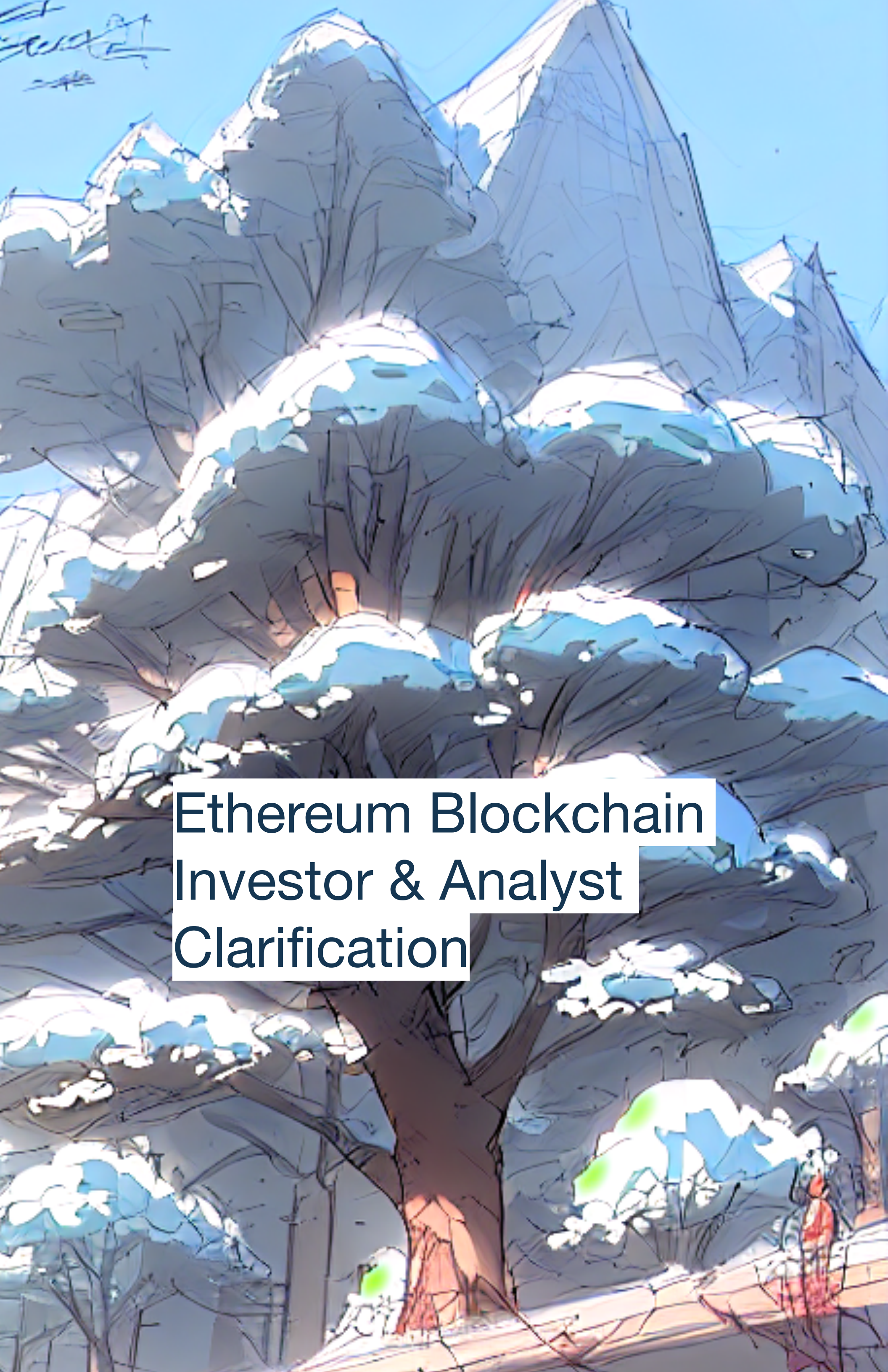

Ethereum Blockchain Investor & Analyst Clarification

Content

March 2025

ETHEREUM BLOCKCHAIN ANALYST & INVESTOR CLARIFICATION

Introduction

Ethereum is the leading decentralized computing platform, powering a global digital economy. As the consistently second-largest cryptocurrency for nearly a decade, it has revolutionized the blockchain space by introducing programmable money and decentralized applications, shaping the future of finance and beyond. For those analyzing and investing in the industry, understanding Ethereum is crucial. This primer offers a technical overview of its value proposition, innovative Proof-of-Stake consensus, and the Maximal Extractable Value (MEV) landscape, providing the essential knowledge for navigating and evaluating opportunities within its ecosystem.

1. Understanding Ethereum

1.1 The Ethereum Blockchain

Ethereum is a decentralized, open-source blockchain network that innovatively adds a programmable layer to the foundation laid by Bitcoin. Launched in 2015 following its 2013 proposal by Vitalik Buterin, Ethereum introduced smart contracts – self-executing code operating without intermediaries. This pivotal innovation has enabled a diverse range of applications, including finance, digital collectibles, and enterprise solutions.

Unlike Bitcoin's primary function as a digital store of value, Ethereum is a flexible platform for decentralized computation. Its global operation relies on a distributed network of validators, ensuring strong resilience and security, positioning it as key infrastructure for a decentralized global digital economy.

Similar to the internet's impact on information, Ethereum, a leading blockchain, is driving the digitization of assets for an expanding global digital economy, enabling a decentralized system independent of intermediaries and government control.

1.2 Ethereum's Native Token: ETH

Ether (ETH), Ethereum's native cryptocurrency, is fundamental to its operation and economy. It serves as both the platform's utility token and a significant digital asset.

ETH is essential for all Ethereum network activity, used to pay transaction fees (gas fees) for processing and recording transactions. It also functions as collateral for staking, a core element of Ethereum's Proof-of-Stake (PoS) consensus. Validators stake ETH to secure the network, optimize resource allocation, and deter malicious activity through slashing penalties.

Beyond its utility for gas fees in the global digital economy, ETH has gained recognition as a store of value and a medium of exchange in the broader cryptocurrency market. Its liquidity and adoption make it the second-largest cryptocurrency by market capitalization, after Bitcoin. ETH's utility and increasing scarcity, particularly with its deflationary economic model, further bolster its value.

2. Ethereum's Intrinsic Value Proposition

Ethereum transcends the paradigm of a mere digital asset, establishing itself as a foundational, programmable infrastructure for a burgeoning decentralized global digital economy. Its mature ecosystem, coupled with its inherent technical innovations and ongoing iterative enhancements, underpins its prominent standing within the blockchain landscape.

2.1 The "Ultra-Sound Money" Thesis and its Role in a Global Digital Economy

The efficacy of a monetary asset as a medium of exchange, store of value, and unit of account is predicated on six fundamental attributes. A comparative analysis across fiat currencies, Bitcoin, and Ethereum reveals nuanced distinctions, as outlined in

Figure 1. Comparative Analysis of Monetary Asset Characteristics

Trait	Fiat (USD, EUR, etc.)	Bitcoin (BTC)	Ethereum (ETH)
Durability	Physical degradation possible; digital fiat is durable	Extremely durable (digital)	Extremely durable (digital)

Portability	Yes, with jurisdictional transfer limitations	Highly portable, borderless	Highly portable, borderless
Divisibility	Yes	Yes	Yes
Fungibility	Yes	Yes	Yes
Scarcity	No (central bank issuance)	Yes (hard cap of 21 million)	Pseudo-deflationary via EIP-1559 burn mechanism; no fixed supply cap
Acceptability	High (government mandate)	Growing adoption	Growing adoption

The inherent characteristics of Ethereum position it favorably relative to traditional fiat currencies. Unlike centrally controlled fiat, susceptible to inflationary pressures through discretionary monetary policy, Ethereum incorporates a deterministic burn mechanism (EIP-1559). This protocol systematically removes a portion of transaction fees (denominated in ETH) from circulating supply, exerting deflationary pressure over time and enhancing its scarcity profile. While Bitcoin's capped supply of 21 million units establishes absolute scarcity, Ethereum matches its digital counterparts in durability, portability, divisibility, and fungibility. Beyond Bitcoin's primary function as a digital store of value, Ethereum's intrinsic utility lies in its capacity to execute arbitrary code through smart contracts, enabling a diverse range of decentralized applications. This programmability distinguishes Ethereum as a versatile and forward-looking asset compared to both Bitcoin and conventional fiat systems.

2.2 Intrinsic Utility: The Programmable Foundation

Ethereum's fundamental value proposition extends beyond its function as a mere cryptocurrency; its true strength lies in its unparalleled versatility as a foundational platform for decentralized applications (dApps). This capability underpins innovation across key sectors, including decentralized finance (DeFi), non-fungible tokens (NFTs), and enterprise-grade blockchain solutions. Smart contracts, as self-executing and trustless agreements, empower developers to construct disintermediated systems, obviating the need for traditional intermediaries. Quantifiable metrics, such as transaction throughput, active user addresses, and developer activity, consistently demonstrate Ethereum's dominant position within the blockchain ecosystem. The aggregate Total Value Locked (TVL) within DeFi protocols serves as a critical indicator of the ecosystem's scale, growth, and overall health. As of March 2025, the distribution of TVL across prominent blockchain networks, illustrated in Figure 2, underscores Ethereum's commanding market share.

Figure 2. Top Blockchains by Total Value Locked (TVL)

Blockchain	Market Share by TVL	TVL (USD Billions)
Ethereum	53.94%	$46.0
Solana	7.86%	$6.71
BNB Smart Chain	5.60%	$4.78
TRON	5.06%	$4.32
Source: CoinGecko as of March 11, 2025		

Qualitatively, Ethereum's programmable architecture has fostered a global ecosystem of diverse projects leveraging its capabilities for unique use cases spanning DeFi, supply chain optimization, and decentralized gaming economies. Current revenue generation within the Ethereum network is predominantly driven by DeFi applications, as depicted in Figure 3.

Figure 3. Ethereum Network Revenue Distribution by Use Case

Use Case	Percentage of Revenue
DeFi	48.7%
Payments	20.4%
Infrastructure	18.8%
Advertising and Marketing	8.9%
Gaming	1.8%
Other	1.4%
Source: VanEck: ETH 2030 Price Target and Optimal Portfolio Allocations	

The genesis of the cryptocurrency movement, including Ethereum, can be partially attributed to the systemic vulnerabilities exposed by the 2008 Global Financial Crisis. The crisis highlighted the inherent risks associated with opaque financial instruments, excessive reliance on centralized intermediaries, and regulatory deficiencies within traditional financial systems. Bitcoin emerged in 2009 as a decentralized, peer-to-peer alternative, offering transparency and autonomy. Ethereum, launched in 2015, extended these principles by introducing smart contract functionality, thereby enabling the development of decentralized financial (DeFi) applications and broader blockchain-based solutions.

2.2.1 The Reshaping of Finance Through DeFi

Stablecoins on Ethereum: Stablecoins, digital assets engineered to maintain a stable valuation typically pegged to a fiat currency, constitute a fundamental building block within the Ethereum DeFi ecosystem. Their stability mitigates the inherent volatility associated with other cryptocurrencies, facilitating seamless transactional activity. The current stablecoin landscape on Ethereum is dominated by fiat-backed assets, a trend reinforced by increasing regulatory clarity, growing institutional adoption, and anticipated legislative frameworks within the United States. The two dominant stablecoins on the Ethereum network are USDC (USD Coin), issued by Circle and fully collateralized by USD-denominated assets, and USDT (Tether), issued by Tether Limited and backed by a diversified reserve of fiat and cash equivalents. Ethereum's robust smart contract capabilities and extensive developer community render it the preferred platform for stablecoin issuance and integration within DeFi protocols. The U.S. administration has also indicated a strategic interest in stablecoins as a potential mechanism to reinforce the global dominance of the U.S. dollar within emerging digital financial infrastructure. The current stablecoin market capitalization approximates $250 billion, with projections indicating substantial growth into the trillions due to their inherent utility.

The Tokenization of Real-World Assets (RWAs): Tokenization represents the process of digitally representing ownership claims of tangible or financial assets – such as real estate, commodities, bonds, or equity – on a blockchain. This mechanism enhances the transferability, divisibility, and global accessibility of these assets. On Ethereum, tokenized RWAs are typically implemented via ERC-20 compliant smart contracts that represent fractional or whole ownership of the underlying asset. These tokens can be traded, utilized as collateral within DeFi protocols, and integrated into various financial applications, unlocking previously illiquid markets. The tokenization of RWAs bridges the gap between traditional finance and blockchain infrastructure, offering advantages such as enhanced transparency through on-chain data, reduced settlement times and transaction costs, and broadened access for global investors. Examples of tokenized RWAs include fractionalized ownership of real estate, tokenized treasury bills and bonds, private credit instruments represented as blockchain tokens, and tokenized securities currently traded on conventional exchanges (e.g., BTCS Inc.).

Lending and Borrowing Protocols: Decentralized lending and borrowing protocols, such as Aave, exemplify Ethereum's capital efficiency and flexibility in reshaping traditional financial paradigms. Unlike conventional lending processes characterized by extensive documentation, credit assessments, and centralized intermediaries, Aave facilitates trustless and permissionless borrowing and lending of digital assets. Figure 4 illustrates the operational complexities of a traditional home loan origination process.

Figure 4. Traditional Finance Example (Home Loan)

[Note: The visual representation of Figure 4 would need to be recreated here, depicting the flow from Depositors to Banks (Intermediaries) to Borrowers secured by Homes.]

The traditional financial system, as depicted, relies on a centralized model where banks aggregate deposits and subsequently extend credit to borrowers against collateral. This process is often protracted (30-60 days), expensive, and encumbered by significant bureaucratic overhead, including extensive paperwork, credit checks, underwriting procedures, title insurance, and regulatory compliance. The reliance on centralized institutions introduces inefficiencies, elevated costs, and restricted access to financial services, underscoring the demand for more agile and inclusive alternatives. Furthermore, traditional finance exhibits limitations in facilitating microtransactions due to high transaction fees, slow processing times, and intermediary dependencies. Minimum balance requirements, regulatory constraints, and processing delays further impede accessibility for individuals seeking to leverage smaller asset holdings or participate in financial markets at a granular level.

In contrast, Aave enables users to instantaneously access liquidity and borrow digital assets without the necessity of traditional banking relationships or credit approval processes. Figure 5 illustrates the mechanics of this decentralized lending and borrowing model leveraging blockchain technology.

Figure 5. Decentralized Finance Example (Aave)

[Note: The visual representation of Figure 5 would need to be recreated here, depicting the flow from Depositors/Lenders and Borrowers interacting directly with the Aave Protocol (Smart Contracts) on the Ethereum Blockchain, with collateral posted.]

Unlike conventional loan structures, Aave permits users to borrow stablecoins (e.g., USDC) and other cryptocurrencies by providing their existing crypto holdings (e.g., ETH, USDC) as collateral, while retaining exposure to the appreciation potential of their collateralized assets. To ensure protocol solvency, Aave employs an over-collateralization mechanism, mandating borrowers to deposit collateral exceeding the borrowed amount. This strategy effectively mitigates risk, even under conditions of significant market volatility. Moreover, deposited assets continuously accrue interest, optimizing capital efficiency beyond the capabilities of traditional financial instruments.

Aave's permissionless nature democratizes access to borrowing and lending irrespective of geographic location or financial standing. All transactions are executed transparently on the Ethereum blockchain, eliminating costly intermediaries and reducing settlement times from months to mere minutes. Leveraging smart contracts, Aave automates and enforces loan terms, removing the potential for human bias and institutional gatekeeping. Operating on a 24/7/365 basis, Aave provides continuous access to financial services independent of traditional banking hours. Figure 6 highlights the key differentiators between Aave and traditional banking systems.

Figure 6. AAVE vs. Bank Comparison

Category	AAVE	Bank
Spread	3.00%[1]	6.62%[2]
Risk	Overcollateralized	Undercollateralized
Operating Hours	24/7, 365 days a year	9 AM – 5 PM Monday – Friday, often closed on holidays

Governance	Computers, Smart Contract Logic, no human error risk (political, monetary, etc.)	Humans: Subject to error and influences (political, monetary, etc.)

The advancements in DeFi, exemplified by protocols like Aave, are facilitating the proliferation of Real-World Asset (RWA) tokenization. This transformative process of representing physical or financial assets as digital tokens on a blockchain unlocks liquidity, enhances accessibility, and creates novel financial opportunities previously unattainable within traditional finance.

2.2.2 Transforming the Gaming Industry: From Pixels to Profit

The global gaming industry represents a dynamic and rapidly expanding sector within the technology landscape. Statistical data indicates a global market revenue of approximately $221 billion in 2024, with projections nearing $700 billion by 2029, fueled by the proliferation of mobile gaming, cloud-based platforms, and increasingly sophisticated in-game economies. Despite this substantial growth, a fundamental limitation persists: players typically lack true ownership of the digital assets they acquire through time and financial investment within these virtual environments. Notably, gaming currently contributes a relatively small fraction (approximately 1.8%) of Ethereum network revenue, indicating a significant area for potential expansion as the ecosystem evolves and integrates more blockchain-enabled, player-owned digital economies.

Limitations of Traditional Game Economies: Conventional gaming environments confine digital assets, such as cosmetic skins, weaponry, or virtual currencies, to their specific gaming platforms. These assets possess no inherent value or utility outside their designated virtual world and are typically under the exclusive control of the game developer. Consequently, players are unable to independently transfer or monetize these digital investments. The obsolescence or shutdown of a game platform invariably renders any accumulated in-game progress or asset value null.

Ethereum's Solution: Verifiable Digital Ownership: Ethereum, as the leading smart contract-enabled blockchain, introduces a paradigm shift in gaming through the concept of verifiable, decentralized ownership of digital assets. Leveraging non-fungible tokens (NFTs) and programmable smart contracts, Ethereum enables the creation of in-game assets that are:

- Player-Owned: Independent of the developer or game platform's control.
- Tradable: Freely exchangeable on open, decentralized marketplaces.
- Interoperable: Potentially usable across different games or virtual environments.
- Monetizable: Convertible into real-world value through cryptocurrency exchanges.

This fundamental shift transforms in-game items from ephemeral, siloed assets into integral components of a broader digital economy.

Immutable: A Case Study in Scalable, Player-Owned Gaming: Immutable, a Layer 2 scaling protocol built on Ethereum specifically for NFTs and blockchain-based games, exemplifies Ethereum's transformative capabilities in this domain. Games such as Gods Unchained and Illuvium utilize Immutable to empower players with genuine ownership of their in-game assets. For instance, every digital card in Gods Unchained is represented as an NFT. Players possess the autonomy to freely buy, sell, or trade these cards on external marketplaces, and their value is independent of the game's lifecycle.

2.3 Balancing Decentralization, Scalability, and Security

Ethereum strategically navigates the inherent trade-offs between decentralization, scalability, and security – a challenge often referred to as the "scalability trilemma," as illustrated in Figure 7.

Figure 7. Blockchain Trilemma

[Note: The visual representation of Figure 7 would need to be recreated here, depicting a triangle with Decentralization, Scalability, and Security at each vertex, illustrating the inherent trade-offs.]

Ethereum currently faces the challenge of selectively optimizing scalability to accommodate increasing transaction demand while preserving a high degree of decentralization. For instance, enhancing transaction throughput by increasing block sizes or gas limits necessitates more robust hardware and network infrastructure for validators. As depicted in Figure 8, this potential shift could marginalize smaller network participants with less powerful hardware or unreliable internet connectivity, potentially compromising the network's broad decentralization. However, with a validator count exceeding 1 million, Ethereum possesses a significant margin for scalability enhancements without substantial compromises to security or decentralization.

Figure 8. Blockchain Trilemma: Ethereum Gas Limit Increase Considerations

[Note: The visual representation of Figure 8 would need to be recreated here, potentially illustrating the trade-off between Gas Limit Increase (Scalability) and potential Decentralization impact.]

In contrast, networks like Solana have prioritized rapid scalability, often at the expense of decentralization. While this approach enables high-speed transactions, it renders the network more susceptible to centralization and potential control by powerful entities. Solana's relatively low validator count (less than 2,000) has manifested in tangible risks, with the network experiencing several high-profile outages due to validator coordination failures, impacting user trust and network reliability. Ethereum's strategic approach prioritizes a cautious balance of decentralization, even if it necessitates measured compromises in transaction speed.

2.4 Economic Model and Deflationary Mechanics

Ethereum's economic model underwent a fundamental transformation on September 15, 2022, with the successful transition to Proof-of-Stake (PoS) consensus via EIP-3675 (the "Merge") and the prior implementation of EIP-1559, which introduced a transaction fee burn mechanism. These upgrades significantly reshaped Ethereum's monetary policy, reducing the issuance of new ETH and introducing a mechanism to gradually decrease its circulating supply.

The Merge marked Ethereum's transition from the energy-intensive Proof-of-Work (PoW) mining algorithm to the more sustainable PoS consensus, replacing miners with validators who secure the network by staking ETH. This transition resulted in a reduction of over 99.9% in Ethereum's energy consumption. Furthermore, the Merge significantly decreased the issuance rate of new ETH, from approximately 13,000 ETH per day under PoW to around 1,700 ETH per day under PoS – an 88% reduction in new supply. During periods of high network utilization, the burning of transaction fees via EIP-1559 can even result in negative net ETH issuance, reinforcing its "ultra-sound money" narrative.

Why EIP-1559 is Significant:

- Deflationary Effect: By permanently removing the base transaction fee from circulation, EIP-1559 introduces a deflationary pressure on the ETH supply. Similar to corporate stock buybacks, reducing the circulating supply can exert upward pressure on the asset's value over time.
- Fee Predictability: EIP-1559 enhances the predictability of transaction fees, mitigating the risk of unexpected cost spikes for users.
- Improved User Experience: A more transparent and predictable fee structure contributes to a more user-friendly

experience, potentially driving greater adoption and network utilization.

How EIP-1559 Operates:

Under EIP-1559, transaction fees are bifurcated into two components:

- Base Fee: This is a mandatory fee levied on all transactions utilizing the Ethereum blockchain. The base fee dynamically adjusts based on network congestion. Higher network activity leads to an increase in the base fee, while lower activity results in a decrease. Critically, the base fee is burned, permanently removing it from the circulating ETH supply, rather than being distributed to validators.
- Priority Fee (Tip): This is an optional fee that users can include to incentivize faster transaction processing. Users requiring expedited confirmation can offer a higher priority fee to validators or block builders to prioritize their transactions.

The Total Transaction Fee is the sum of the Base Fee and the Priority Fee.

Outcomes:

Since the Merge and the full implementation of EIP-1559, the issuance rate of new ETH has been substantially reduced, bolstering ETH's appeal as a store of value. The deflationary mechanism introduced by EIP

3. Proof-of-Stake (PoS) Consensus Mechanism in Ethereum

Ethereum's transition to a Proof-of-Stake (PoS) consensus mechanism in September 2022, through the network upgrade termed "The Merge," represents a significant paradigm shift in blockchain security and operational efficiency. This upgrade superseded the computationally intensive Proof-of-Work (PoW) model with a staking-based system, yielding substantial improvements in energy consumption, network security, and overall sustainability.

A core tenet of Ethereum's PoS framework is the act of staking Ether (ETH). Participants are required to escrow a specified quantity of their native asset as a collateral commitment to the network's integrity. These stakers, known as validators, assume the responsibility of maintaining network decentralization and are economically incentivized for adhering to protocol specifications. Conversely, malicious behavior or failure to meet performance benchmarks are subject to punitive measures, including the slashing (confiscation) of staked ETH, thereby ensuring alignment of individual incentives with the network's collective well-being. This mechanism not only bolsters Ethereum's resilience but also fosters responsible network participation through predictable, protocol-defined rewards. The scalability of staking participation directly correlates with the enhanced robustness of Ethereum's network security, further solidifying the efficacy of its PoS consensus mechanism.

3.1 Ethereum's Dual-Layered PoS Architecture

Ethereum's PoS consensus architecture is predicated on a bifurcated system comprising the **Consensus Layer** (formerly designated as Ethereum 2.0 or the Beacon Chain) and the **Execution Layer** (representing Ethereum's original mainnet). The Consensus Layer is primarily responsible for the validation of transactional data and the security of the underlying blockchain, while the Execution Layer handles the computational execution of transactions and smart contracts. The synergistic operation of these two layers ensures the operational integrity and functional coherence of the Ethereum network.

At the core of the PoS mechanism lies the concept of **validators**. These are network participants who perform the critical functions of proposing new blocks and attesting to the validity of blocks proposed by others. This is achieved by operating validator client software and maintaining a staked balance of ETH. This economic incentivization model replaces the computational race inherent in PoW blockchains like Bitcoin, aligning participant interests with the overall health and security of the network. **Figure 16** illustrates the temporal growth in the total number of Ethereum validators and the aggregate amount of ETH staked on the network.

Figure 16. Total Ethereum Validators and Staked ETH

[**Note:** The visual representation of Figure 16 would need to be recreated here, depicting a graph showing the increasing trend of both Total Ethereum Validators and Staked ETH over the period from January 1, 2021, to January 1, 2025, sourced from Beaconcha.in.]

The geographically diverse distribution of Ethereum's validator base, exceeding 1 million participants across over 70 countries (as depicted in **Figure 17**), is paramount for ensuring network decentralization and security. This widespread distribution mitigates the risk of centralization, where control could be concentrated within a limited number of entities or geographical regions, and enhances the network's resilience against localized disruptions or jurisdictional regulatory actions. By operating validator nodes across diverse legal and physical infrastructures, Ethereum fortifies its position as a globally decentralized platform, ensuring continuous and secure operations independent of regional vulnerabilities.

Figure 17. Ethereum Validator Distribution by Region

Country	Validator Distribution
United States	57.61%
Germany	9.66%
United Kingdom	3.17%
Canada	2.99%

France	2.89%
Netherlands	1.96%
Singapore	1.61%
Russia	1.21%
Belgium	1.14%
Source: Etherscan Node Tracker as of March 10, 2025	

Export to Sheets

Comparison to Proof-of-Work (e.g., Bitcoin):

Ethereum's strategic transition from a PoW to a PoS consensus mechanism addressed several inherent limitations of mining-based systems, including but not limited to:

1. **Energy Efficiency:** PoS exhibits a significantly lower energy consumption profile, estimated at approximately 99.95% less than PoW, thereby eliminating the requirement for energy-intensive computational mining operations.
2. **Economic Accessibility:** The barrier to entry for network participation in PoS is currently defined by the requirement to stake 32 ETH (or participate via pooled staking mechanisms), as opposed to the substantial capital expenditure and ongoing operational costs associated with specialized PoW mining hardware.
3. **Enhanced Security:** PoS strengthens network security by requiring a substantial economic commitment (in ETH) to potentially compromise the network, rendering malicious attacks prohibitively expensive.

This strategic evolution underscores Ethereum's commitment to environmental sustainability and its adaptive capacity to meet the evolving demands of the global blockchain ecosystem.

3.2 Validator Overview and Rewards Structure

Validator Selection and Slot Mechanics:

The selection process for a validator to propose a new block of transactions for inclusion on Ethereum's blockchain is probabilistically determined, a design feature critical for maintaining network security and preventing collusive behavior. A validator is pseudo-randomly selected approximately 6.4 minutes in advance to propose a block within each 12-second slot. This randomness is achieved through cryptographic techniques, ensuring that no single validator can deterministically predict or influence their selection. By distributing block proposal responsibilities and enforcing penalties for inactivity or malicious actions, Ethereum's PoS design minimizes centralization risks and fosters a robustly secure network environment.

Validator Roles and Rewards:

Validators fulfill critical roles within Ethereum's Proof-of-Stake consensus, ensuring the network's security, decentralization, and operational functionality. Their responsibilities are broadly categorized into two primary activities:

1. **Block Proposals:** Within each 12-second slot, a validator is probabilistically selected to propose a new block of pending transactions. The selected validator constructs the block and disseminates it to the network. In return for this service, the proposer earns **execution rewards** derived from the gas fees associated with the transactions included within the proposed block, providing a direct economic incentive for efficiently processing high-value network activity.
2. **Attestations:** Validators who are not selected to propose a block during a given slot are responsible for providing **attestations** regarding the validity of blocks proposed by other validators. Attestations are fundamental to achieving network-wide consensus and ensuring the integrity of the blockchain. Validators are compensated with **consensus rewards** in ETH for submitting accurate attestations, which contribute to the finalization of blocks and the overall security of the network.

Economic Incentives in Proof-of-Stake:

Validators accrue staking rewards through two primary economic mechanisms, which collectively incentivize their active and responsible participation in securing the network:

- **Execution Fees:** These are the gas fees paid by network users for the inclusion of their transactions within a proposed block. These fees are directly earned by the validator selected to propose the block and fluctuate based on network congestion and the volume of transactional activity.
- **Consensus Rewards:** These rewards, denominated in ETH, are distributed by the Ethereum network to validators proportionally to their staked ETH and their active participation in attesting to proposed blocks. Accurate and timely attestations are crucial for achieving finality and maintaining the network's integrity.

Figure 18 illustrates the approximate distribution of validator rewards, with roughly 80% derived from Execution Fees (gas fees) and 20% from Consensus Rewards. This distribution underscores the importance of both block proposal and attestation activities in ensuring robust network consensus.

Figure 18. Breakdown of Validator Rewards: Consensus vs. Execution Fees

[**Note:** The visual representation of Figure 18 would need to be recreated here, depicting a pie chart or bar graph showing approximately 80% of validator rewards coming from Execution Fees and 20% from Consensus Rewards, sourced from the provided URL.]

Furthermore, staking rewards provide a consistent income stream for validators. By locking 32 ETH to become eligible and active on the network, validators earn ETH rewards influenced by several factors:

- **Network Participation Rate:** An increase in the overall number of active validators and the total amount of ETH staked leads to a decrease in the individual yield for each validator due to a fixed reward issuance schedule. This dynamic is analogous to Bitcoin mining, where an increase in the network hash rate for a constant individual hash rate results in a reduced share of the block reward.

- **Validator Performance:** Consistent and timely block proposals and attestations are essential for maximizing reward accrual. Conversely, validator downtime or malicious behavior results in penalties, including the slashing of staked ETH.

This economic structure effectively aligns the incentives of individual validators with the overall security and stability of the Ethereum network, encouraging honest and reliable participation.

3.3 Liquid Staking Pools

Liquid staking pools offer a mechanism for individuals to participate in Ethereum staking and earn rewards while maintaining the liquidity of their staked assets, typically in exchange for a service fee. Prominent liquid staking providers such as Rocket Pool, Lido, and Stader function as intermediaries, aggregating smaller ETH contributions from numerous users to collectively meet a portion of the 32 ETH staking requirement per validator node. This arrangement enables a broader range of participants, including professional validator operators who may not individually possess 32 ETH per node, to engage in staking. However, validators participating through liquid staking pools are still required to contribute a portion of the staked ETH; for example, Rocket Pool validators are currently required to stake 8 ETH, with the remaining 24 ETH supplied by the pool's collective deposits.

Professional validator operators utilizing staking pools manage the technical and operational complexities associated with running secure and efficient validator infrastructure. In return for their services, participants receive a liquid staking derivative token, such as rETH (Rocket Pool) or stETH (Lido), representing their pro-rata share of the staked ETH and accrued rewards. These liquid staking tokens enable participants to earn staking rewards, net of pool fees, while retaining the flexibility to trade or utilize their staked capital within DeFi applications or on centralized exchanges such as Coinbase, Kraken, and Binance. For instance, Rocket Pool distributes staking rewards to rETH holders after deducting an operational fee, which is then shared between the validator operators and the Rocket Pool protocol. This economic model incentivizes professional validator operators by providing them with enhanced revenue potential compared to independently operating validator nodes.

4. Ethereum Transaction Lifecycle: A Fundamental Overview

The lifecycle of an Ethereum transaction encompasses a series of sequential stages, commencing with user initiation and culminating in its permanent inclusion and settlement on the blockchain. A comprehensive understanding of this process is paramount for the analysis of network performance metrics, gas fee dynamics, and user interaction patterns. **Figure 19**provides a visual representation of the constituent phases of a transaction, from its initial creation to its final on-chain commitment.

Figure 19. Ethereum Transaction Lifecycle - Basic

[**Note:** The visual representation of Figure 19 would need to be recreated here, depicting a flowchart or diagram illustrating the sequential steps of the Ethereum transaction lifecycle, from User Initiation to Block Inclusion and Finalization.]

User Initiates Transaction

Every Ethereum transaction originates with a user-driven action, which can include the transfer of Ether (ETH), interaction with a deployed smart contract, or the submission of an order within a Decentralized Finance (DeFi) protocol. Each initiated transaction comprises several key data elements:

- **Sender Address:** The cryptographic address of the Ethereum wallet initiating the transaction.
- **Recipient Address:** The cryptographic address of the destination wallet or the address of the target smart contract.
- **Value:** The quantity of ETH or specified tokens being transferred to the recipient address.
- **Gas Price:** The unit price of gas (denominated in Gwei) that the user is willing to pay for the computational resources required for transaction execution. This parameter influences the transaction's priority for inclusion in a block.
- **Nonce:** A sequential, transaction-specific counter associated with the sender's address. The nonce ensures the uniqueness and correct ordering of transactions originating from a particular wallet, preventing replay attacks.

Upon creation, the transaction is cryptographically signed using the sender's private key (analogous to a digital signature), providing cryptographic integrity and non-repudiation. This signed transaction is then broadcast to the Ethereum network for dissemination and eventual inclusion in the mempool.

Mempool: The Pending Transaction Pool

The mempool (memory pool) serves as a publicly accessible, temporary holding area for all valid, pending transactions that have been broadcast to the network but have not yet been included in a finalized block. Validators actively monitor the mempool to select transactions for incorporation into the next block they propose. Conceptually, the mempool can be likened to a waiting queue where all submitted transactions await processing and confirmation by the network.

Block Inclusion

Validators, operating within the Proof-of-Stake consensus mechanism, are responsible for constructing and proposing new blocks of transactions to be appended to the Ethereum blockchain.

These proposed blocks contain a subset of the transactions currently residing in the mempool, ordered according to the validator's selection criteria (often prioritizing transactions with higher gas prices).

Validation and Consensus

Once a block is proposed by a validator, it undergoes a rigorous attestation process by other validators within the network. This validation phase encompasses several critical checks:

- **Transaction Authenticity:** Verification of the cryptographic signatures associated with each transaction within the proposed block, ensuring they were indeed initiated by the purported sender.
- **Protocol Compliance:** Confirmation that all transactions adhere to the established rules and specifications of the Ethereum protocol.
- **Smart Contract Execution:** For transactions interacting with smart contracts, validators execute the relevant code to ensure the integrity and correctness of the state transitions resulting from the transaction.

During this attestation phase, validating nodes submit their votes (attestations) on the validity of the proposed block. These attestations collectively determine whether a sufficient supermajority of the network agrees on the block's validity. Once a block receives the required number of attestations within an epoch (comprising 32 slots, or approximately 6.4 minutes), it achieves **finality**. Finality signifies that the block is permanently recorded on the blockchain and cannot be subsequently altered or reversed.

Upon inclusion of a transaction within a finalized block, it is considered **confirmed**. Users can track the status of their submitted transactions in near real-time through blockchain explorers such as etherscan.io and beaconcha.in. These tools provide detailed information regarding a transaction's mempool status, the amount of gas consumed during execution, and the specific block in which the transaction was included.

Gas Optimization and User Behavior

Gas fees represent a fundamental economic mechanism within the Ethereum transaction lifecycle, directly influencing the cost of interacting with the network. To mitigate these costs, users often employ various optimization strategies:

- **Timing:** Strategically submitting transactions during periods of lower network congestion, when demand for block space is reduced, typically results in lower gas prices.
- **Batching:** Aggregating multiple related operations into a single, more complex transaction can amortize the base cost of transaction submission and potentially reduce overall gas consumption compared to executing each operation individually.
- **Layer 2 Solutions:** Leveraging Layer 2 scaling platforms (such as rollups) allows users to execute transactions with significantly lower gas fees while still inheriting the security guarantees of the underlying Ethereum Layer 1 for final settlement.

5. Ethereum Transaction Lifecycle: Integration with Maximal Extractable Value (MEV)

5.1 Understanding Maximal Extractable Value (MEV)

Maximal Extractable Value (MEV) denotes the incremental profit that a block proposer (validator) can realize by strategically manipulating the ordering, inclusion, or exclusion of transactions within a block. Initially perceived as an inherent consequence of Ethereum's permissionless architecture, MEV has matured into a substantial economic force, exerting significant influence on network dynamics and the end-user experience. **Figure 20** illustrates the integration of MEV considerations within the various stages of an Ethereum transaction's lifecycle.

Figure 20. Ethereum Transaction Lifecycle with MEV

[**Note:** The visual representation of Figure 20 would need to be recreated here, depicting a flowchart or diagram illustrating the sequential steps of the Ethereum transaction lifecycle, with specific points highlighting MEV extraction opportunities during the Mempool and Block Inclusion phases, and the involvement of Searchers, Builders, and Relays.]

Fundamentally, MEV arises from the inherent flexibility in Ethereum's transaction processing. Validators and specialized block builders possess the capability to extract value by exercising control over the sequential arrangement of transactions within a block.

The transaction lifecycle intersects with MEV extraction opportunities most prominently during the mempool phase and the subsequent block inclusion process. A sophisticated and specialized ecosystem of actors—including searchers, block builders, and relays—has emerged, establishing an auction-based system that significantly benefits validators by optimizing block rewards. Since its introduction post-Merge, the Proposer Builder Separation (PBS) framework has witnessed rapid and widespread adoption, establishing itself as the dominant paradigm for validators to delegate block construction to specialized entities.

Figure 21. MEV-Boost Adoption

[**Note:** The visual representation of Figure 21 would need to be recreated here, depicting a graph illustrating the adoption rate of MEV-Boost over time, sourced from mevboost.pics.]

Total Market Size: $2-4 Billion[3]

Market Size: The aggregate market size encompassing validators and builders is estimated to be within the range of $2 to $4 billion[3], with Ethereum block builders generating approximately $400 to $800 million[4] in annualized revenue.

The specialized sub-sector of block building has evolved into a significant revenue driver within the Ethereum ecosystem. Builders accrue transaction fees by strategically prioritizing, including, or excluding transactions within a block to maximize profitability, particularly during periods of heightened network congestion.

5.2 Key Participants in the MEV Ecosystem

Ethereum's ecosystem is characterized by a diverse array of participants, each vying for limited block space to execute transactions, finalize trades, and optimize on-chain activities. From market makers and centralized exchanges to specialized MEV searchers and Layer 2 networks, these actors play a crucial role in maintaining market liquidity, ensuring transaction settlement, and scaling the network, all while competing for efficient and timely inclusion within Ethereum blocks. Notably, these participants often route their transaction order flow directly to block builders via private channels, bypassing the public mempool.

Private Order Flow: Non-Public Transactions

The practice of users directly routing their transactions to block builders mirrors the use of "dark pools" by brokerage firms and trading desks in traditional stock markets. In dark pools, equities are traded privately to avoid signaling market intentions and potentially influencing prices adversely. Similarly, within Ethereum, private order flow enables users such as market makers, MEV protection services, Layer 2 networks, and centralized exchanges to prevent their transactions from being observed or potentially manipulated prior to execution. Block builders who receive private order flow can offer superior execution guarantees by constructing blocks without the risk of public competition or front-running.

This practice yields benefits for both the users and the block builders. Users gain enhanced privacy and potentially more favorable execution terms, while block builders secure exclusive access to high-value transaction fees, providing them with a competitive advantage in profitability and efficiency over builders relying solely on publicly broadcast mempool transactions.

Market Makers:

Market makers are entities that provide liquidity to both decentralized and centralized exchanges by continuously quoting bid and ask prices for various assets. Firms such as Wintermute and Jump Crypto play a critical role in stabilizing market prices, reducing slippage, and improving the efficiency of trade execution. Some market makers strategically employ MEV techniques to optimize their profitability while actively managing the inherent risks associated with maintaining substantial liquidity positions.

MEV Protection Services:

MEV protection services, including platforms like Blink, Merkle, and Flashbots Protect, are specifically designed to safeguard users from exploitative MEV strategies such as front-running and sandwich attacks. These services achieve this by keeping user transactions out of the public mempool through private transaction routing, batching mechanisms, and alternative transaction ordering strategies, thereby enhancing transaction security and predictability.

Layer 2s:

Layer 2 scaling solutions play a pivotal role in enhancing Ethereum's transaction throughput by processing transactions off-chain and subsequently settling them in batches on Ethereum's mainnet (Layer 1). As the adoption and transaction volume on Layer 2 networks increase, they generate significant demand for Layer 1 block space, as L2 transaction batches must ultimately be finalized on the base layer. Protocols such as Arbitrum and Optimism aggregate multiple user transactions into a single batch before submitting them to Ethereum, competing for inclusion in blocks to ensure timely and cost-effective finalization.

Exchanges:

Centralized exchanges (CEXs) generate substantial demand for Ethereum block space as they facilitate user deposits, withdrawals, liquidations of margin positions, and internal fund transfers between user wallets or across different blockchain networks. Unlike decentralized exchanges, where every trade is directly settled on-chain, CEXs primarily operate off-chain but require frequent interaction with blockchains for settlement purposes.

Major CEXs such as Binance, Coinbase, and Kraken regularly move significant volumes of cryptocurrency on-chain to manage their internal liquidity, facilitate institutional-scale trades, and process customer withdrawals. These on-chain transactions compete for inclusion in Ethereum blocks, particularly during periods of high market volatility when users exhibit increased activity in moving funds into or out of exchange platforms.

Searchers (i.e., Traders):

Searchers are independent participants who specialize in identifying and capitalizing on MEV opportunities through active on-chain trading strategies. Their role is critical within the MEV ecosystem, as they meticulously craft transaction bundles and execute trades designed to extract profit. These trade bundles consist of carefully ordered, interdependent transactions engineered to achieve a specific profitable outcome, such as arbitrage between different markets or the liquidation of undercollateralized DeFi positions.

Unless they operate with vertical integration, searchers typically do not directly participate in block-building auctions. Instead, they submit their meticulously crafted trade bundles directly to block builders, relying on the builders to include their transactions within a proposed block. To mitigate the risks of front-running by other MEV actors or the leakage of their proprietary trading strategies, searchers often utilize private communication channels to deliver their transaction bundles to trusted block builders, or increasingly, they vertically integrate their operations by running their own block-building infrastructure. This approach ensures a greater degree of confidentiality and control over their trading activities.

Examples of prevalent MEV strategies include:

- **Arbitrage:** Exploiting transient price discrepancies for the same asset across different decentralized or centralized exchanges by executing simultaneous buy and sell orders.
- **Back-Running:** Strategically placing a transaction immediately following a target transaction to profit from the market impact or state change induced by the initial transaction.
- **Front-Running:** Submitting a transaction with a higher gas price to be included in a block before a pending target transaction, thereby capitalizing on the anticipated market movement or state change that the target transaction is expected to trigger.
- **Liquidations:** Within Decentralized Finance (DeFi) protocols, liquidations occur when a borrower's collateral value falls below the protocol's required loan-to-value ratio. MEV actors actively compete to execute these liquidations as quickly as possible, as they often receive a "liquidation bounty" or the ability to purchase the collateral at a discounted price. Given the time-sensitive nature of liquidations, searchers typically pay elevated gas fees to ensure their liquidation transactions are prioritized for inclusion in the next block.

While arbitrage and back-running generally contribute to market efficiency by stabilizing prices and eliminating global price discrepancies across trading venues, front-running has significant negative implications for end-users, potentially leading to increased transaction costs, reduced liquidity, and altered transaction outcomes.

MEV exists across various blockchain networks but is particularly prevalent and economically significant on Ethereum due to its robust and highly liquid DeFi ecosystem, which presents numerous arbitrage and liquidation opportunities, fostering a highly competitive market for block space.

5.3 Block Builders

Block building is a foundational process within Ethereum, encompassing the critical tasks of selecting, ordering, and assembling individual transactions into a coherent block that adheres to the network's technical specifications and economic constraints. With the advent of Ethereum's Proof-of-Stake consensus mechanism and the implementation of the Proposer Builder Separation (PBS) model, block building has evolved into a more specialized and optimized market aimed at maximizing validator rewards.

Overview of Block Building:

The block-building process commences when a validator is probabilistically selected to propose the next block to the Ethereum network. The block builder, which can be the proposing validator themselves or an outsourced specialized entity (such as BTCS), performs the following key steps:

1. **Transaction Selection:** Transactions are chosen from the public mempool or from private order flow sources, with a focus on prioritizing transactions offering higher gas fees or bundled transactions designed to extract MEV, thereby maximizing potential rewards.
2. **Transaction Ordering:** The builder strategically arranges the selected transactions within the block to optimize profitability. This ordering is crucial for capturing MEV opportunities such as arbitrage and back-running.
3. **Block Assembly:** The selected and ordered transactions are packaged into a valid block structure that adheres to Ethereum's gas limit constraints and all other established protocol rules.
4. **Submission:** The constructed block is then transmitted via a trusted relay to the proposing validator, who subsequently broadcasts it to the broader Ethereum network for attestation and inclusion on the canonical blockchain.

Proposer-Builder Separation (PBS):

Ethereum's PBS framework represents a significant architectural decoupling of the roles of block proposers (validators) and block builders. Validators primarily focus on their core responsibilities of securing the network through staking and proposing blocks when selected, while specialized block builders engage in a competitive market to assemble the most profitable blocks. As the MEV ecosystem matures, participants are increasingly adopting more specialized roles within this value chain.

How PBS Works:

- Specialized block builders participate in a competitive auction process, submitting bids that represent the payment they are willing to make to validators in exchange for having their pre-built block proposed to the network.
- Validators, when selected to propose a block, evaluate the bids received from various builders and select the block that offers the highest reward (typically the block associated with the highest bid).
- The validator then proposes the selected block to the network for the standard validation and attestation process.

The implementation of PBS has significantly expanded the MEV market by enabling specialized participants to create and capture more value, thereby contributing to the overall growth and efficiency of the Ethereum ecosystem. This framework fosters the development of niche expertise, allowing block builders to concentrate on maximizing profitability through sophisticated MEV extraction strategies, ultimately enhancing the network's economic viability.

PBS Auctions:

Block building under the PBS model operates through a recurring 12-second auction cycle, corresponding to Ethereum's slot duration. During each slot, builders submit bids to eligible validators, offering a payment in exchange for the validator proposing their pre-built block. This auction mechanism enables validators to maximize their earnings from block proposals by outsourcing the complex task of block construction to specialized builders, thereby allowing even less technically sophisticated validators to remain economically competitive.

Tools such as payload.de provide real-time and historical data and visualizations of PBS auctions, offering insights into the bidding dynamics and the characteristics of blocks built by different entities. **Figure 22** showcases an example of a block constructed by BTCS, along with the competing bids submitted leading up to the 12-second slot time deadline.

Figure 22. PBS Auction Visualized on Payload.de

[**Note:** The visual representation of Figure 22 would need to be recreated here, showing a screenshot or depiction of the Payload.de interface displaying the details of a specific block (e.g., #22005181 built by BTCS) and the associated bids from competing builders.]

Block Building and MEV:

MEV is intrinsically linked to the block-building process. Builders actively optimize the profitability of the blocks they construct by strategically extracting MEV through the careful ordering and bundling of transactions sourced from both the public mempool and private order flow. Validators directly benefit from outsourcing their block-building responsibilities, receiving a larger share of the MEV revenue in the form of payments from the winning block builder in the PBS auction.

Competitive Landscape / Concentration of Market Share:

The competitive landscape of Ethereum block building reflects the dynamic interplay between validators, specialized builders, and MEV extraction entities. The advent of Proposer Builder Separation and the increasing prevalence of MEV opportunities have fostered a dynamic marketplace with significant revenue potential and strategic implications for the network.

The block-building market is currently characterized by a mix of independent participants and larger, highly specialized entities. While Ethereum's decentralized ethos encourages broad participation, certain market forces and technical advantages have led to a noticeable concentration of market share among a few dominant players.

Currently, there are approximately 16 active block builders participating in the PBS auction, with the top 5 builders accounting for an estimated 99% of all blocks produced on the Ethereum network. This significant concentration of block production raises concerns regarding potential centralization risks, as a small number of entities wield disproportionate influence over the network's operational aspects. **Figure 23** illustrates the current distribution of market share among the leading block builders.

Figure 23. Builder Market Concentration

Builder	Searche r	Builder Relay	Validator Market
Titan	✓	✓	48.8%
Beaver	✓	✓	36.5%
Rsync	✓	✓	11.0%
BTCS	✓	✓	1.9%
Builder Net		✓	1.0%
Source: Builder Market share obtained from Rated Explorer on			

Export to Sheets

Competitive Dynamics:

The observed consolidation within the block-building market presents several potential challenges to the long-term health and decentralization of the Ethereum network:

1. **Economic Inequalities:** Smaller validators and nascent block builders may face significant challenges in competing effectively with established professional builders who possess superior technical infrastructure, access to private order flow, and sophisticated MEV extraction capabilities,

potentially exacerbating disparities in block-building rewards.

2. **Regulatory Concerns:** As the MEV market continues to grow in economic significance, increased regulatory scrutiny on block builders could lead to the imposition of censorship and compliance restrictions, potentially impacting the neutrality and permissionless nature of the network.
3. **Reliance on the Existing System:** For validators seeking to maximize their profitability from block proposals, outsourcing block production to professional builders via the PBS auction has become the dominant and most economically viable strategy. The lack of widely adopted alternative solutions effectively creates a dependency on this centralized system, reinforcing the dominance of a few key block builders in Ethereum's block production process.

Revenue Opportunities in Block Building:

The growth trajectory of block builder revenue is driven by several key factors that directly influence MEV extraction potential and the dynamics of the block auction:

1. **Price of Ethereum:** A higher prevailing market price for ETH directly increases the fiat value of block rewards (transaction fees and MEV), making block building a more lucrative activity.
2. **Transaction Activity:** Increased overall network utilization, particularly during periods of high market volatility, typically leads to higher transaction fees and more abundant MEV opportunities, thereby increasing the potential revenue for efficient block builders.
3. **Expanding Products and Services:** Technological advancements and the development of novel on-chain applications can create additional revenue streams for block builders beyond traditional transaction inclusion, such as specialized MEV extraction services or optimized block construction for specific application types.

As Ethereum continues its scaling efforts and the adoption of decentralized applications grows, the potential for revenue growth within the block-building sector is projected to increase significantly, further shaping how builders and validators approach block construction and reward optimization. This growth may be further catalyzed by innovative projects like ETHGas, which aims to develop a new marketplace for gas on Ethereum. This development has the potential to unlock ultra-low-latency scaling capabilities on Ethereum's blockchain, enabling transaction confirmations significantly faster than current Layer 1 speeds and potentially expanding the overall market share with novel transaction processing products.

Figure 24. ETHGas - The Future of Gas Markets[6]

[**Note:** The visual representation of Figure 24 would need to be recreated here, showing a graphic or key information from the ETHGas "The Gas Stack Presentation."]

5.4 Relays

Relays function as trusted intermediaries within the PBS auction mechanism, ensuring a fair, transparent, and secure bidding and settlement process between block builders and validators. Operating akin to an escrow agent in traditional financial transactions, a relay facilitates the exchange of information and value by verifying and forwarding the highest-bidding builder's block header to the validator while simultaneously preventing the validator from inspecting the block's contents before committing to accepting the bid.

Once a validator accepts a bid, the relay performs a crucial role in verifying the validity and integrity of the full block submitted by the winning builder before securely forwarding it to the validator for unmodified inclusion on the Ethereum blockchain. This system provides essential protection for builders against potential front-running or censorship by validators, while simultaneously enabling validators to confidently outsource block construction to specialized entities to earn higher rewards without requiring specialized technical expertise or infrastructure. By enforcing fairness and integrity within the PBS auction process, relays play a critical role in the functioning and efficiency of Ethereum's MEV marketplace.

5.5 Validators

Within Ethereum's Proof-of-Stake system, validators serve a critical dual role: they secure the network by attesting to the validity of blocks proposed by their peers and they are also probabilistically selected to propose new blocks to be added to the blockchain. While validators retain the technical capability to construct their own blocks, the overwhelming majority—currently estimated to be over 90%—opt to sell their block proposal rights (block space) to sophisticated block builders through the Proposer Builder Separation (PBS) auction mechanism. This strategic decision allows validators to maximize their earnings from block proposals while minimizing the technical complexity and infrastructure requirements associated with effective block building and MEV extraction.

When a validator chooses to participate in the PBS auction by selling their block space, their primary source of revenue for that specific block proposal opportunity becomes the payment offered by the highest-bidding block builder. Conversely, for block builders, the payment made to the validator represents their cost of sales, as they are effectively purchasing the exclusive right to the validator's block space for that designated 12-second slot. This auction