SOLANA VALIDATORS AND FEE ECONOMICS

The Meaning of Validators and Fee Economics in Cryptocurrency Systems.

The two terms validators and fee economics are used in the concept of Proof-of-Stake (PoS) in cryptocurrency systems or blockchain networks. Solana validators are associated with the Proof-of-Stake (PoS) and Proof-of-History (PoH) as a consensus mechanism in the Solana ecosystem. Solana validators are nodes or computers that validate transactions and create new blocks on the Solana blockchain. The Solana fee economics is the way transaction fees are achieved and distributed in the Solana blockchain.

The Roles and Significance of Validators in The Solana Ecosystem.

Solana validators are responsible for running the Solana protocols and creating new blocks on the blockchain after validating credible transactions. The Solana validators give the blockchain a decentralization feature and they are vital to the Solana's blockchain scalability. Solana validators also secure the ecosystem by executing programs that keep track of all the accounts on Solana clusters as independent entities making it difficult for attackers to alter the clusters.

Solana validator's requirements are not too much, there is no mandatory amount of SOL to be staked to become a validator. A validator can only take part in consensus by having a voting account with 0.02685864 SOL as a rent-exempt reserve and sending a vote transaction of about 1.1 SOL in value for each block he agrees with. The minimum hardware requirements to become a Solana validator are given in the table below.

Basic Hardware and Software Requirements for A Solana Validator.

CPU	RAM	DISK	GPUs
12 cores / 24 threads, or more 2.8GHz base clock speed or faster. SHA extension instruction support AMD Gen 3 or newer. Intel Ice Lake or newer. AVX2 instruction support (to use official release binaries, self-compile otherwise) Support for AVX512f is helpful	256GB or more Error Correction Code (ECC) memory is suggested. A motherboard with 512 GB capacity is suggested.	PCIe Gen3 x4 NVME SSD, or better. Accounts: 500GB, or larger. High TBW (Total Bytes Written) Ledger: 1TB or larger. High TBW suggested OS: (Optional) 500GB, or larger. SATA OK The OS may be installed on the ledger disk, though testing has shown better performance with the ledger on its disk. Accounts and ledger *can* be stored on the same disk, however, due to high IOPS, this is not recommended. The Samsung 970 and 980 Pro series SSDs are popular with the validator community.	Not necessary at this time. Solana operators in the validator community do not use GPUs currently

The software requirement for Solana validators is Ubuntu 20.04 (recommended). For more information on the Solana validator's requirements check docs.solanalabs and watch the YouTube video Spotlight: Solana validators and hardware requirements. Validators earn rewards for their services as a transaction fee or with newly minted tokens.

Challenges Faced by Validators on Solana and Potential Solutions.

Solana validators are facing challenges ranging from high hardware and bandwidth requirements to network congestion and latency, centralization, censorship and slashing risks as well as volatility and uncertainty of rewards. According to Rob Behnke, steep hardware requirements are hindering running a Solana validation node. This is why Solana has only 2,364 validators compared to 440,263 validators on Ethereum as of February 2023. The solution to this is getting more validators without compromising the security, fast speed and low transaction cost that the network is known for.

Network outages have become a norm in the Solana ecosystem. The blockchain experienced 14 network outages in 2022, there was one outage in 2023 on February 25 and one outage was recorded in February 2024. According to Rob Behnke, Solana outages are caused by the inability of Solana validators to handle high transaction loads during peak periods looking at it on a high level. There are not enough validators to spread the workload which eventually leads to network collapse. The tendency for bots to spam the Solana blockchain is high due to its all-time very cheap transaction cost. On the side of the network engineers, bugs have been identified as the root cause of Solana outages. For instance, the cause of the February 5, 2023 outage was traced back to several services on the network running custom block-forwarding software that inadvertently transmitted a huge amount of data, equivalent to several orders of magnitude larger than a normal block. The network's de-duplication logic was unable to cope with this, overwhelming the Turbine protocol and significantly degrading the network. Solana blockchain core engineers have been implementing and rolling out different network upgrades to solve the outage problem. They have implemented QUIC, fee markets and stake-weighted Quality of Service (QoS) to address the problem. The engineers claimed that QUIC will replace all the UDP-based networking protocols and will be better at enforcing the constraints in the Turbine for a more stable network.

The centralization challenge for the Solana validators arises from the need to increase the hardware requirement for increasing the validator's capability to handle more transactions efficiently. The more stringent the hardware requirements, the higher the cost of running a Solana validator node and the less the number of validators. This will cause centralization rather than decentralization of the Solana blockchain. The best solution is to increase the fees for the congested dApps and retain low fees for normal transactions. This approach retains the decentralization feature of the Solana blockchain, its low cost and prevents bot attacks that cause network outages.

The Structure and Distribution of Fees within the Solana Network and Their Role in Validator Economics.

Solana has two fee structures the transaction fees and the state fees. The state fee is subdivided into a base fee and a priority fee. The base fee is fixed at 0.000005 SOL at 5000 lamports per signature. A priority fee is usually indicated in the transaction and denominated in microlamports per CU. Transaction fees are paid at the onset of transaction execution and failure to do so renders a transaction invalid and not executed. Half of the transaction fees are kept as an incentive to the leader-validator for including the transaction in the blocks and the remaining half is burned. This design is aimed at retaining leader incentives to include several transactions within its slot time. It provides an inflation-limiting mechanism that prevents tax evasion attacks. The design also reduces the incentive to the censors giving room to detect a malicious censor leader. For instance, in the case of a PoH fork with a malicious censor leader, the total fees destroyed will be less compared to that of an honest fork.

Solana charges a state fee called a rent exemption fee to create a new state. The rent exemption fee is 6.96 SOL per MB and it is assigned to a newly created validator account. Solana transaction fees are set by the network cluster based on the historical throughput and it can be adjusted based on the historical gas usage.

The roles of the transaction fees are many in the validator economics. They provide unit compensation to the validator network for resources used to process the state transaction. They introduce real cost to transactions

and therefore reduce network spamming. They open avenues for a transaction market to incentivize validators to accept and process transactions. They introduced a protocol-captured minimum fee per transaction which provides a potential long-term economic stability of the Solana network.

Comparative Analysis of Fee Economics Between Solana and Other Major Blockchains.

The three major blockchains that can be compared on a fee economics level are Solana, Polygon and Ethereum. The other blockchains are behind these three. Using the metrics of transaction fees and gas price, Ethereum has a notorious high gas price according to the Blockchain Council. According to the council, Ethereum gas prices and fees usually reach hundreds of dollars per transaction during peak periods and it frustrates smaller transactions. Polygon unlike Ethereum has lower gas prices and transaction fees which is linked to its Proof of Stake consensus algorithms that reduce energy consumption and cost on the network.

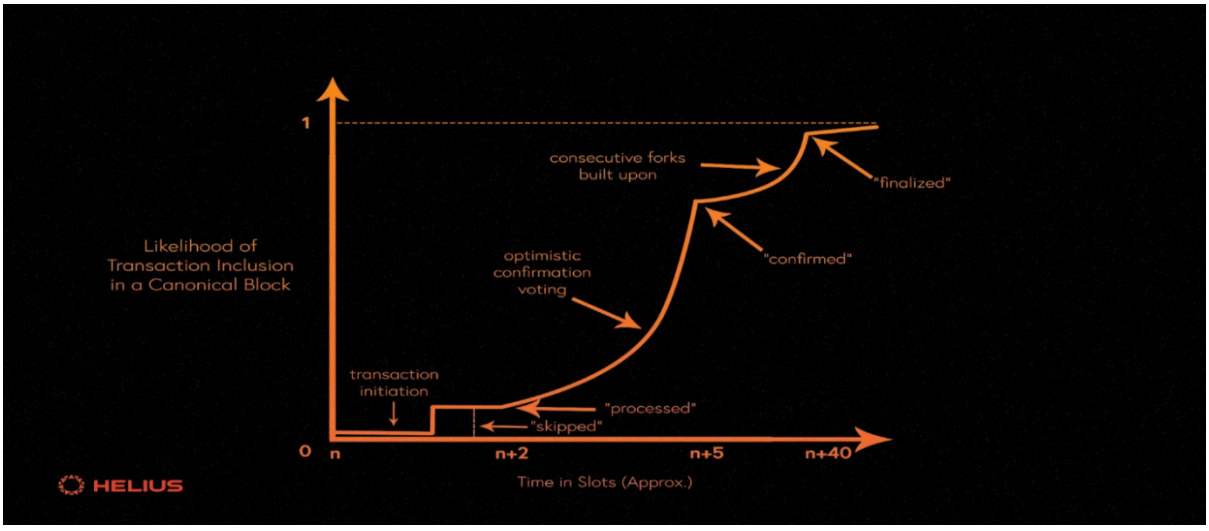
In comparison to both Ethereum and Polygon, Solana blockchain stands out with its unique consensus mechanism which combines both Proof of Stake and Proof of History. According to the Blockchain Council, Solana has extremely low transaction fees, charging a few cents per transaction. The network has high throughput, an efficient consensus algorithm, and quick and inexpensive transaction fees. The gas price on the three networks is shown in the table below. Polygon gas price is paid in MATIC while Solana gas price is 0.0001 SOL all converted to their present dollar equivalent at the time of writing.

Gas Price on Ethereum, Polygon and Solana Blockchains.

Blockchain Network	Gas Price ($)
Ethereum	Several Hundred during peak periods
Polygon	0.097
Solana	0.01

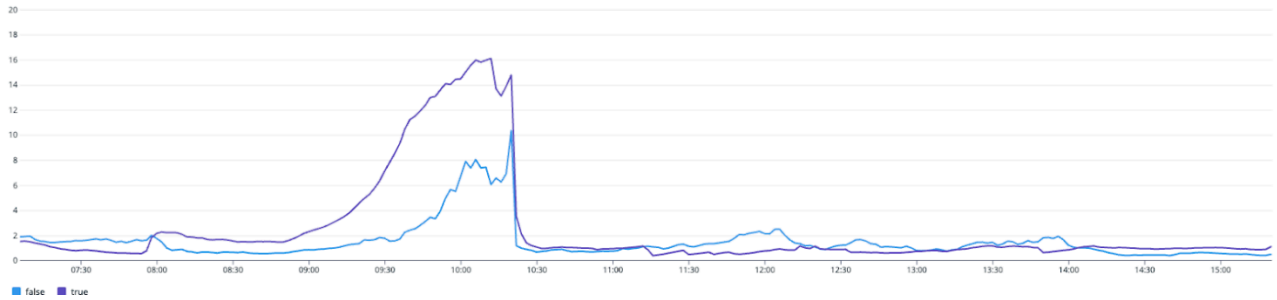
The Impact of Fee Economics on Network Performance, User Experience and Validator Incentives.

Transaction fee is mandatory to get a transaction executed but other factors determine whether a transaction will be executed and added to a block. A validator may lag in block processing, there may be a discrepancy within an RPC pool and the loss of a UDP network packet may lead to transaction drop-off. The loss of a UDP network packet may occur during the peak periods when validators have more transactions than they can handle until the blockhash expires. When a transaction's recent blockhash is retrieved from an updated segment and later submitted to a slower segment it may lead to discrepancy within an RPC pool. A transaction's block may end in the minority fork as a result of its validator block processing lagging. Such a block ends up being dropped off.



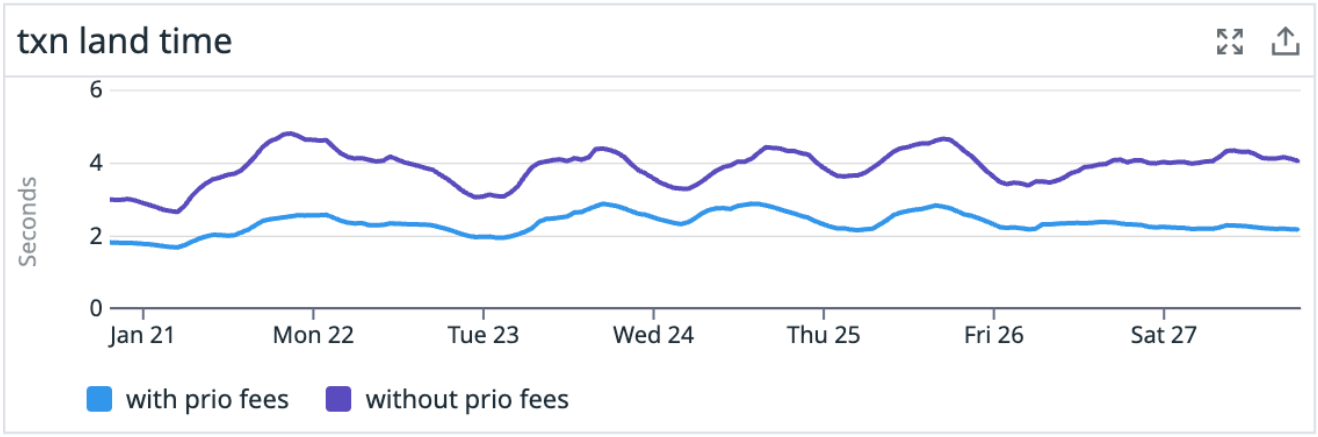
Consensus on Solana blockchain. (Source: Helius.dev)

In another view, there is evidence that priority fees influence block inclusion on a macro scale but not perfect. Helius RPC data shows that transactions with priority fees have more chances of block inclusion and the higher the priority fees the greater the chance of block inclusion. This is shown in the graphs below, True is the transactions with the priority fee while the y-axis shows the percentage of transactions.



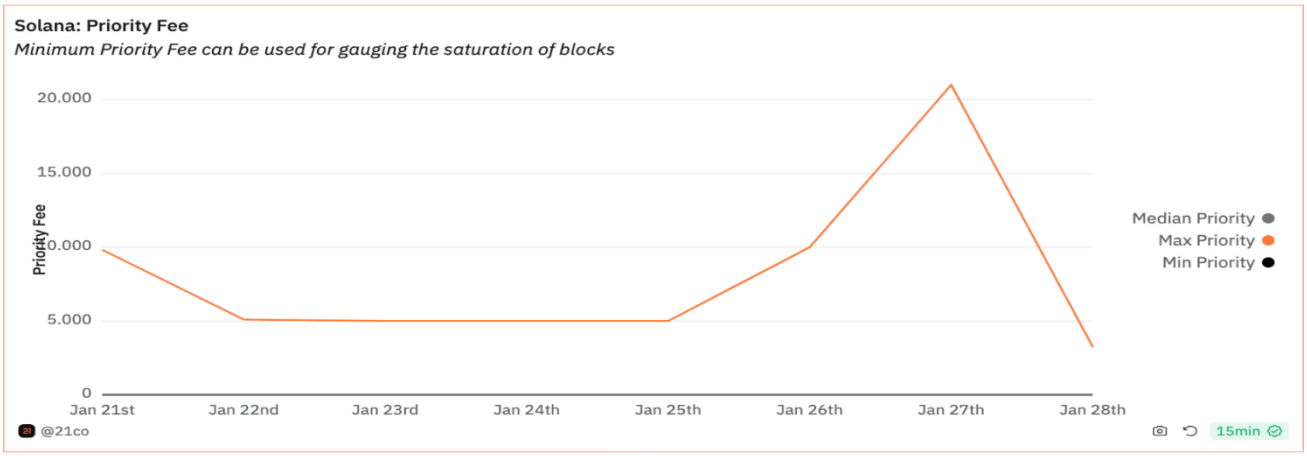
True = transactions with priority fees, y-axis = Percentage of transactions.

Effect of priority fee on block inclusion. (Source: Helius.dev)



Effect of priority fee on block inclusion. (Source: Helius.dev)

The second graph also shows that transactions with priority fees also land quickly.

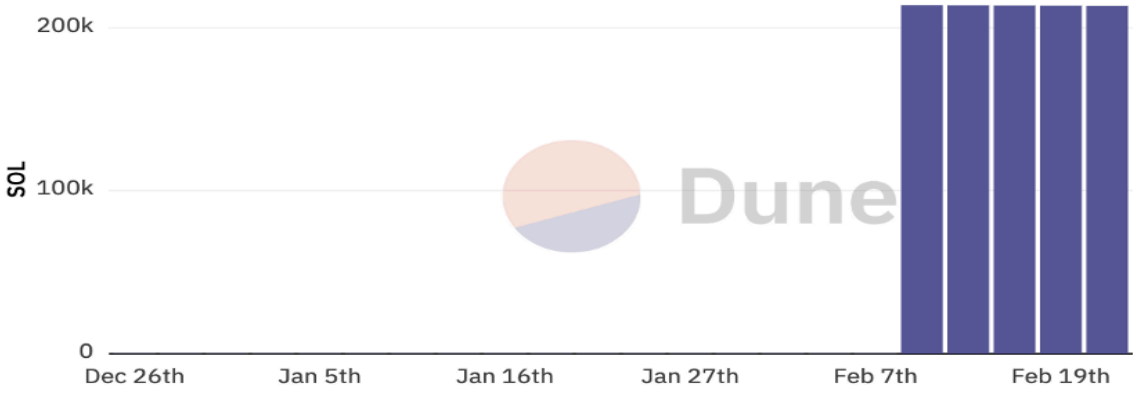


Solana Priority Fee: (Source: Helius.dev)

According to Ryan Chern, Solana priority fees experienced an increase in average on January 21, 2024, caused by the mockJUP airdrop has the real JUP airdrop was around the corner. It increases the demand for blockspace and affects users' transaction time and transactions' land rate. As shown above, the Solana RPC method (getRecentPrioritizationFees) assists developers in determining the priority fees to assign for a

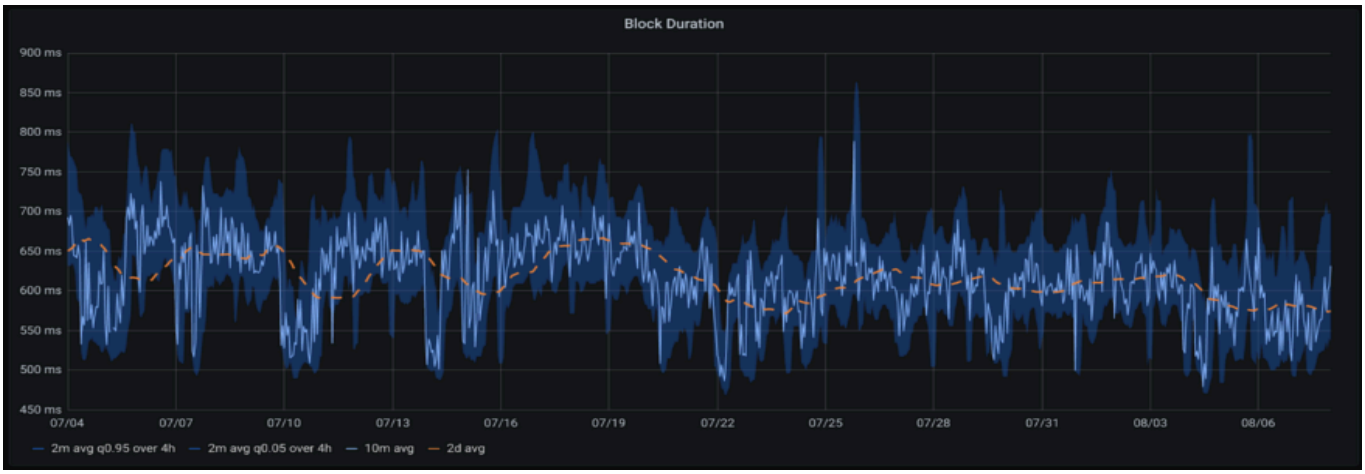
transaction. Helius also offers a Priority Fees API that allows additional calculations to determine the best priority fees for a transaction.

It can be stated that Solana validators' incentives come from transaction fees as discussed above and from a protocol-based reward. A protocol-based reward is realized from inflationary issuances from a protocol-defined inflation schedule. Solana inflation design was defined at 8% SOL emissions and reduced by 15% every year. It was activated on February 10th, 2021 with a payment of 213841 SOL according to the Chorus One blog quoting the Solana validator dashboard.



Solana validators started to receive rewards from inflation on February 10, 2021.

Solana inflation models consider 400ms block time, the present average is about 650ms. A longer block time will result in smaller rewards to validators when the number of epochs (specified consensus operation time) per year is small as shown in the chart below.



Solana block times over the 35 days ending August 9, 2022.

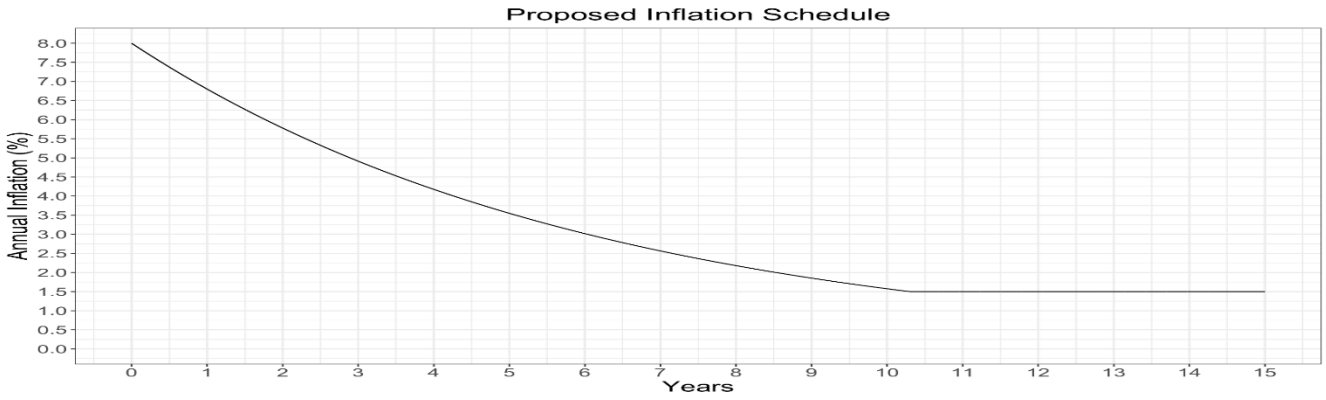
The Potential for Negative Commission Rates in Scenarios where Network and Maximum Extractable Value (MEV) Fees Become Sufficiently High.

Maximum Extractable Value (MEV) is the profit that miners or validators can extract through the ordering and execution of transactions strategically within a block. Miners or validators therefore determine the order of transaction especially in front-running or arbitrage where such transaction may offer profit. During periods of network congestion users may compete by paying high prices to have their transactions quickly processed. A validator can try to extract more value through MEV opportunities. Negative commission rates come in when validators are willing to pay users by lowering the commission rates even to a negative value to attract users to

delegate with them. Negative commission rate is more supported MEV is prevalent and profitable or when the validator is after maximizing profit.

On the Solana network validators complete the transaction not miners. These validators are grouped in clusters to vote on the validity of a transaction while each validator acts as a leader to avoid corrupt practices in the validation process. This makes only some MEV possible on Solana. According to the Chorus One blog, from July 16 to July 26, 2022, Orca and Raydium recorded 68 MEV with a lower bound of $20,775.

Analysis of The Long-Term Economic Viability of Validators as Solana's Inflation Approaches Its Terminal Value.



Example of proposed inflation schedule graph on Solana. (Source: Solana doc)

Solana's inflation schedule is based on the initial inflation rate of 8%, disinflation rate of -15% and long-time inflation rate of 1.5% according to the Solana documentation. Solana has a decreasing inflation rate that will approach its terminal value over time, the time when the Solana network's token supply will be stabilized. The rate at which new tokens are minted will reduce with a reduction in the validator's incentive. The reason is that the validator's reward comes from transaction fees and staking rewards while staking rewards include the new token mints and transaction fees distributed among validators based on their participation in consensus and the amount staked.

The economic viability of a Solana validator depends on its ability to generate income that is above its operational cost. As inflation approaches its terminal value on Solana, the reward for a validator depends more on the transaction fees as the block rewards decrease. This is where Solana's low cost will assist the validators to be economically viable. For individual validators, validators must offer competitive staking rewards and additional services to attract and retain more users staking with them.

Potential Models or Innovations That Could Support Validator Sustainability under Low Inflation Conditions.

The sustainability of validators under low inflation periods requires alternative revenue apart from rewards from blocks. One of the major potential models for the sustainability of the validator under low inflation conditions on Solana is the implementation of a fee-burn mechanism. The mechanism aims at creating deflationary pressure on native tokens on Solana. It should be recalled that half of the transaction fee is burnt hence permanently removed from the ecosystem. This has an impact on increasing the value of the native tokens from which validators will earn more incentives in the long run.

Validators need to add additional services to attract more users to stake with them. For instance, a validator may add analytic tools or API access to their service. More users will stake their tokens with them to access these value-added services. Validators can also collaborate with projects in the ecosystem by offering integrations or services that will enhance the overall Solana network utility.

There is room for validators to participate in DeFi protocol integrations. Here they can offer services like liquidity providing, asset staking or governance roles. This gives them opportunities to increase their profitability. They can also issue collateralized stable coins and leverage their staked assets.

Validators can also participate in community incentive programs to increase overall network usage and service awareness. They can participate in grants, token distributions, sponsorships and other reward programs that drive active network usage and engagements. A very good example of this is this write-up sponsored by Cogent Crypto. Cogent Crypto is a distinguished validator on the Solana network. They have an annual percentage yield (APY) of 7.74%, a cluster average APY of 7.43% and 1,538,862 delegated SOL. You can contact Cogent Crypto to learn more about them.

The Role of Transaction Fees, Staking and Other Economic Mechanisms in Ensuring Ongoing Validator Incentives.

Transactions on Solana are finalized by validators who put them into blocks by consensus mechanism hence the ongoing incentives for Solana validators help in maintaining the network's security, stability and decentralization. To maintain the ongoing Solana validators incentives transaction fees, staking and other mechanisms such as block rewards key instruments. It has been established in the sections above that transaction fees are one of the primary sources of revenue for the Solana validators and one of the major sources of revenue as the Solana inflation rate approaches its terminal value.

Solana validators need a reserve of 0.02685864 SOL and to stake SOL tokens to participate in the consensus mechanism. The staking is a collateral that serves as a security deposit to enhance the interest of the validator in the overall Solana network security. The staking also allows the validators to earn staking rewards in the form of newly minted tokens and transaction fees.

Block rewards are another mechanism that ensures Solana validator's incentives. These block rewards consist of newly minted tokens and transaction fees earned by validators for validating and adding new blocks to the blockchain. It can be categorically stated that transaction fees, staking and other mechanisms that ensure the ongoing Solana validators incentives strengthen the relationship between the users, the validators and the network itself. They aid in security enhancement, decentralization and the stability of the Solana ecosystem.

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