



**Deep Research**

# Cardano Update

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*\*Please see page 29 for required disclosures*

# Executive Summary

- Cardano is an open-source, decentralized, proof-of-stake blockchain that aims to provide a sustainable infrastructure for the development and secure execution of smart contracts for dApps.
- Cardano's smart contract capability was implemented in September 2021 with the Alonzo hard fork enabling a dApp ecosystem. The Vasil hard fork in September 2022 improved smart contract functionality with larger block sizes, shorter block creation intervals, on-chain data sharing with an upgrade to Plutus v2. This leads to reduced latency and lower costs for dApps.
- The most recent Cardano upgrade, Valentine, added new native cryptographic primitives to the Plutus language, boosting interoperability and options for developers.
- Cardano's Hydra is a layer-2 scaling solution that allows participants to establish state channels (hydra heads) using smart contracts. Decentralized auctions using smart contracts eliminate intermediaries for secure and transparent deal execution with immutable data storage.
- Cardano's Voltaire Era is focused on governance for 2023. CIP-1649 upgrades include on-chain participation of ADA holders, greater transparency, and a Cardano Constitution. A Member Based Organization (MBO) will amplify community participation in Cardano's development with different tiers of influence and direct seats on the board.
- Cardano uses a unique functional programming language, Haskell, and a UTXO-based model. To ensure long-term success, IOG has focused on growing its developer community through educational efforts to increase adoption.



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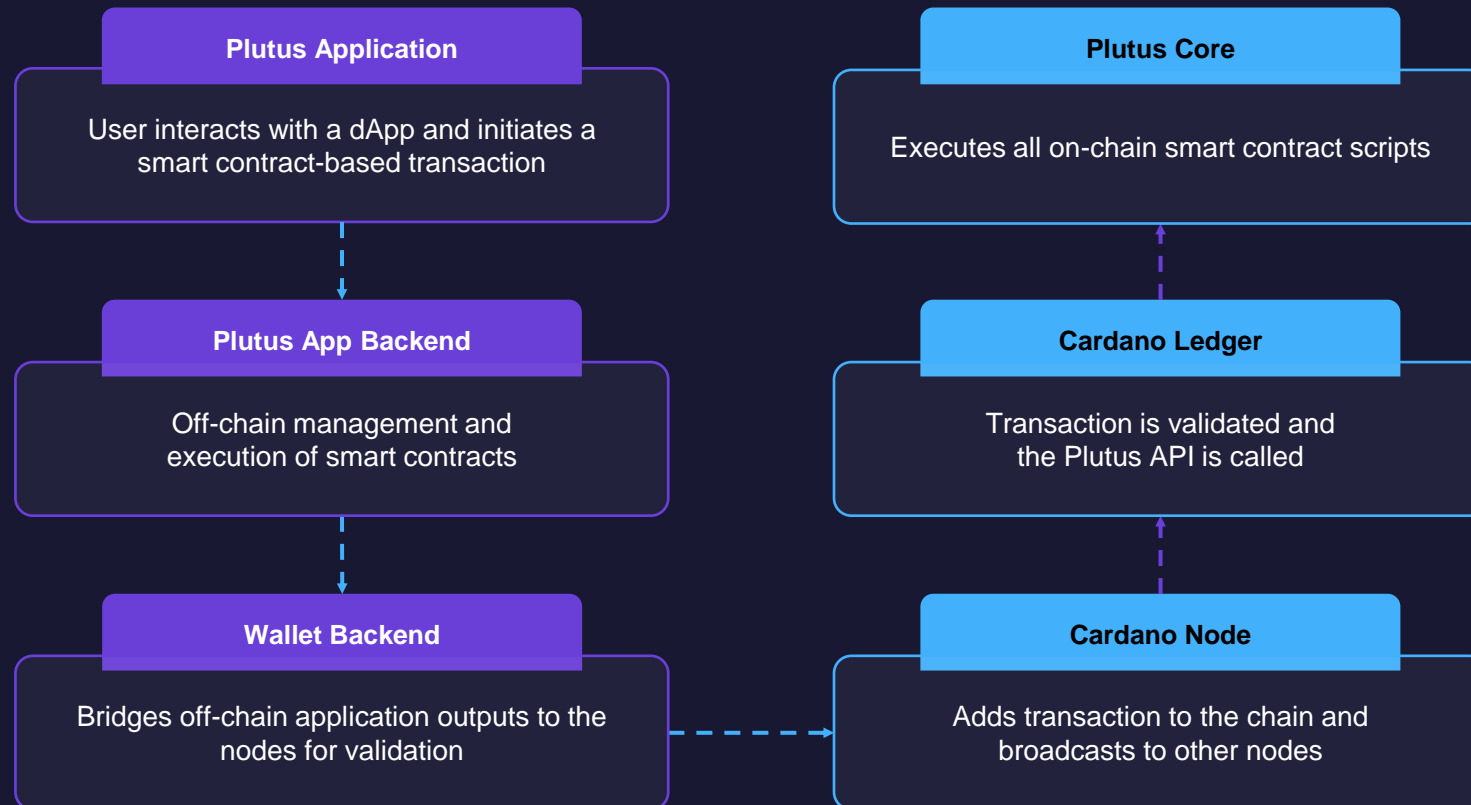
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# Plutus v1: Smart Contracts and Cardano Refactoring

- IOG implemented smart contract capability on Cardano in Sep 2021 with the Alonzo hard fork, enabling the development of a DeFi ecosystem. The smart contract language on Cardano is known as Plutus.
- Smart contracts require more data per transaction than simple value transfers. Consequently, Cardano encountered instances in which mainnet launches of DeFi applications resulted in high latency and low throughput. IOG attributed these early challenges to a lack of developer education and more network optimization requirements. The launch of Plutus v2 following the Vasil hard fork addressed many of the required upgrades.



# Vasil Hard Fork: Plutus v2

- In September 2022, Cardano completed the Vasil hard fork, which addressed issues arising from increased activity with the roll-out of Plutus smart contract capabilities (Alonzo Hard Fork). The updates in the Vasil Hard Fork allow for more throughput using on-chain data sharing and transaction pipelining.
- The Plutus smart contract language was upgraded to Plutus v2, improving Cardano's smart contracts functionality and allowing dApps to run with reduced latency and lower costs.

## Key Plutus v2 Features

### CIP-31: Reference Inputs

- Reference inputs are transaction inputs linked to a transaction output, except that rather than spending the output like normal, it simply references the output.
- This allows the script input to be referenced without being spent, enabling multiple scripts to reference the same input concurrently.

### CIP-32: Inline Datums

- Datums are information attached to outputs; the network had previously required both hashes of the Datum and the actual Datum itself for each transaction.
- This removes the requirement for inputs to be hashed.

### CIP-33: Reference Scripts

- Reference scripts are attached to outputs and referred to during validation.
- This allows previously stored scripts to be referred to by other transactions directly on chain, helping to reduce transaction size and cost.

### Redeemers in Transaction Info

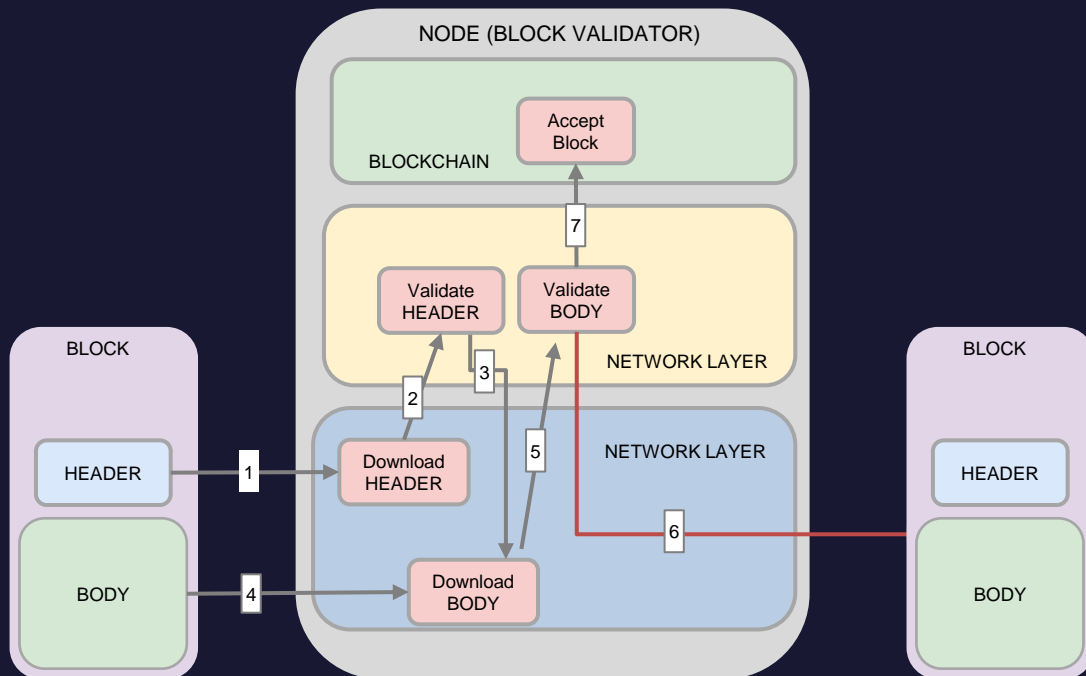
- A redeemer is the data that a user of a smart contract inputs into the smart contract.
- Scripts can now collaborate by using common redeemers.



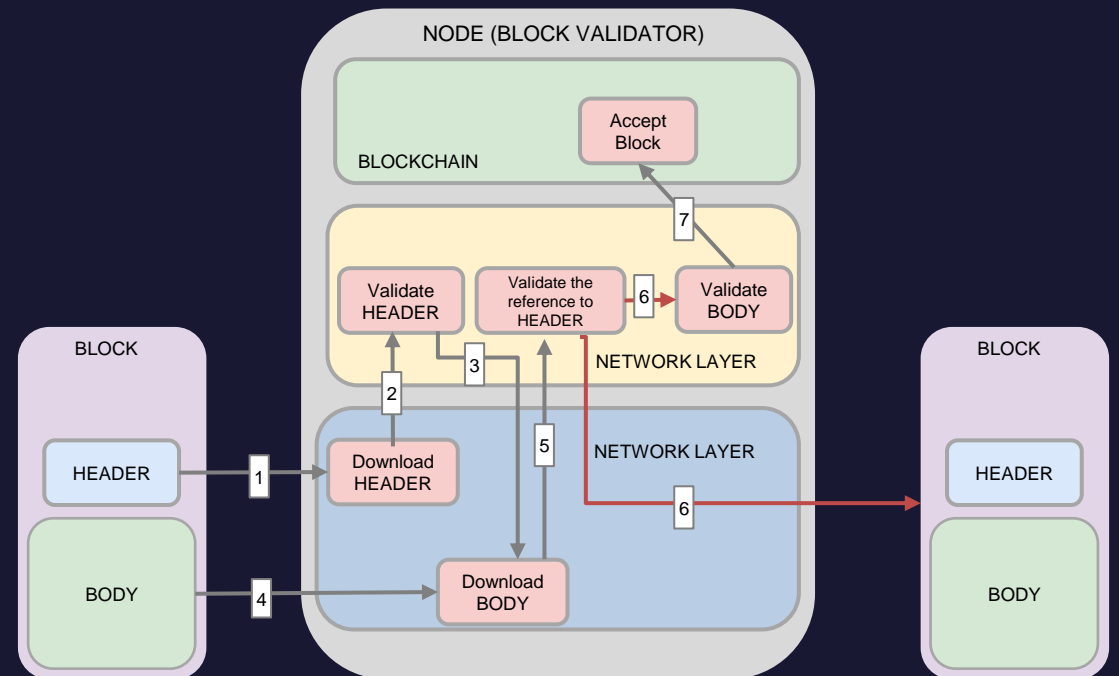
# Vasil Hard Fork: Diffusion Pipelining

- Diffusion pipelining increases the speed of network block distribution by having the block validator send the block body to the network before validating the contained data. If the reference between the header and body is accepted, the block is immediately propagated to the network.
- The total budget for distributing blocks is reduced by the time that would've been spent validating a block's entire body.
- Concurrent block body validation and block distribution via diffusion pipelining significantly increases the speed of data availability.

## Without Diffusion Pipelining

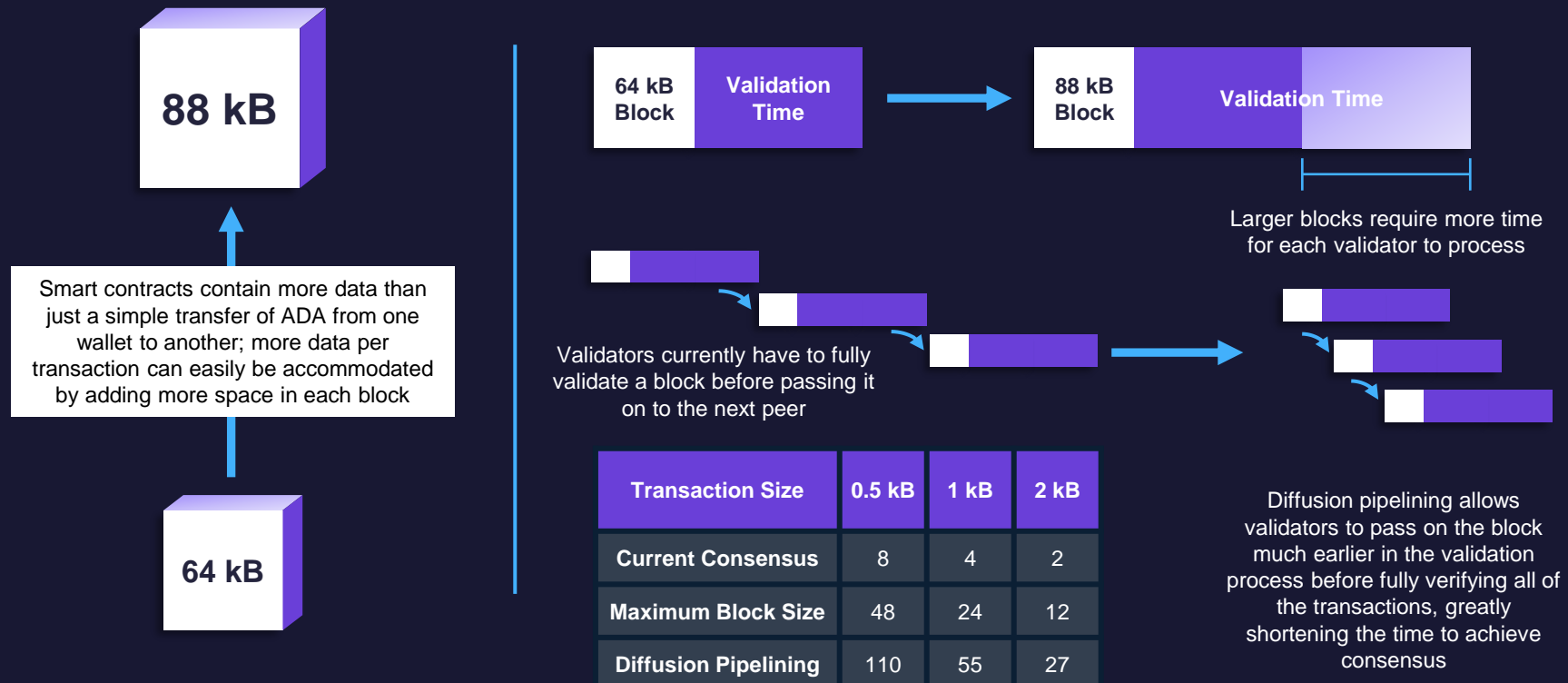


## With Diffusion Pipelining



# Vasil Hard Fork: Block Size Increase

- Increasing block size allows more data to be added to the blockchain every epoch, increasing transaction throughput. A larger block size allows the network to handle more data-intensive transactions like DEX swaps and NFT mints. The 30-day average block size\* is approximately 30 kB vs. a maximum of 88kB, indicating the potential for Cardano to scale transaction throughput.
- Diffusion pipelining allows blocks to be propagated to other nodes while they are still being validated, enabling multiple nodes to validate blocks concurrently. This prevents larger blocks from slowing the consensus process.
- Developers believe these solutions will result in an immediate scalability increase and should help mitigate congestion during the ongoing rollout of smart contract-enabled dApps.



# Implementing Auction Projects Using Hydra

- Hydra is Cardano's layer-2 scaling solution which consists of smart contracts and software that allows any group of participants to establish isomorphic, multiparty state channels (hydra heads) with each other.
- Decentralized auctions use smart contracts to execute a deal between two counterparties. The use of blockchain auctions eliminates centralized entities and commissions.
- Auctions allow for automatic deal execution with immutable and transparent data storage while maintaining data security.

	Cardano Main Chain (L1)	Hydra Head Channels (L2)
Transaction Throughput	<ul style="list-style-type: none"> <li>• Less capable for high-frequency or large volume interactions.</li> <li>• Limits the number of bids and prevents them from reaching full sale price.</li> </ul>	<ul style="list-style-type: none"> <li>• Higher throughput and faster transaction finality allow the bidding frequency to be increased in auctions.</li> </ul>
Transaction Finality	<ul style="list-style-type: none"> <li>• Transaction finality time is slower than in a Hydra head</li> </ul>	
Costs	<ul style="list-style-type: none"> <li>• Higher transaction costs due to multiple auction bids.</li> </ul>	<ul style="list-style-type: none"> <li>• Cheap transaction fees reduce costs for bidders, sellers, and auction houses.</li> </ul>
Cardano Layer-1 as Underlying Ledger	<ul style="list-style-type: none"> <li>• Isomorphic smart contracts would allow significant re-use of layer-1 smart contracts in Hydra heads, ensuring a potentially flexible deployment between L1 and L2 chains.</li> <li>• Reduce development and audit costs while providing the same security guarantees as on the layer-1 chain.</li> </ul>	





# A Focus on Governance

- Developers are prioritizing governance in 2023 as the network enters its Voltaire development phase. The aim of Voltaire is to make the Cardano network a self-sustaining system with active community-driven governance. (For a breakdown of all historical and ongoing eras see slide 28).

## Voltaire Plans

### On-Chain Governance – CIP-1694

- Cardano Improvement Proposal (CIP) 1694 was proposed in November 2022 by a multidisciplinary team from IOG and CF with additional community input. This proposal outlines the mechanism for Cardano's on-chain governance.
- CIP-1694 upgrades include the following:
  - **Allow ADA holders to actively participate in governance** – ADA holders will have an opportunity to raise their voice through their delegate representative (DRep), ensuring every individual is able to truly contribute to shape the future of the protocol.
  - **Provide greater transparency** – CIP-1694 provides more layers of control around movements from the Cardano treasury.
  - **Introduce a Cardano Constitution** – The Constitution will define the rights and principles for those participating in the Cardano ecosystem. Currently an off-chain document with its hash is recorded on-chain, but it may eventually be evolved into a smart-contract-based set of rules that drive Cardano's governance framework.

### Members Based Organization (MBO)

- The MBO is a key institution for the ecosystem, bringing together companies, developers, individuals and other ecosystem participants to shape and drive the future development of Cardano.
- A steward of the underlying blueprints and technology for the community beginning with the Cardano Node, Core Cardano libraries the components required to operate the protocol and all its accompanying documentation, knowledge, and contributors.
- It will be an administrator of processes that govern the continued roadmap and development of the Cardano platform and protocol.
- All participants in the Cardano ecosystem are welcome to become MBO members. Made up of a distributed group of participants, including the foremost experts on Cardano and current ecosystem contributors, the MBO will facilitate healthy discussions and sound decision making amongst its members, and the community at large, to uncover pain points, while championing successes.
- The Cardano MBO will support the most important open-source projects within the ecosystem.



# Developer Relations

- Cardano uses the functional programming language Haskell as a primary language for the core node. Fewer developers use Haskell, which presents a challenge, but tooling is written to enable the use of other languages to assemble transactions. Today it is possible to use RUST to assemble native Cardano transactions with relative ease. While Cardano's eUTXO model is unique, developers are now able to get support more quickly due to the expanding ecosystem and direct support from IOG.
- IOG, Emurgo and the Cardano Foundation have sought to increase developer education with direct participation via Discord in past six months.

## Hackathons

- IOG has recently held in-person hackathons, such as the one held in Austin, Texas.
- Hackathons are a way to attract developers to the ecosystem. They give developers a chance to collaborate and facilitate competitions with rewards for winners.

## Community Engagement

- IOG, Emurgo and the CF have several community led projects that contribute to the developer experience on Cardano. These include demeter.run (dev tooling), mesh.martify (open-source library), and blockfrost.io (set of highly used APIs).
- Community led Project Catalyst has had over 1,500 ideas submitted in the last funding round and 1.7 million votes cast on the proposals.

## Pioneer Programs

- IOG launched Plutus and Atala Pioneer Programs to recruit and train developers for the Cardano ecosystem.
- These programs are free and teach the core principles of coding in both Haskell and Plutus. They are interactive and include weekly videos, Q&A sessions, exercises, and access to experts in the languages.

## Vasil Upgrade

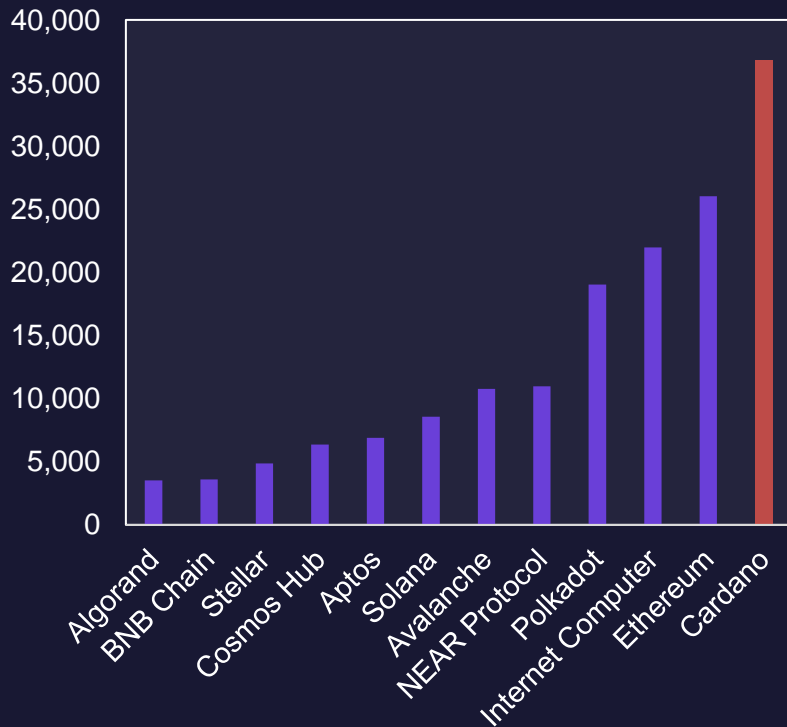
- Cardano's Vasil upgrade in late 2022 enhanced Cardano's functionality, performance, and scalability. This upgrade has provided the needed capabilities for more protocols to deploy on Cardano.
- Innovative dApps such as Indigo Protocol have deployed since this upgrade with more planning to in Q1 2023.



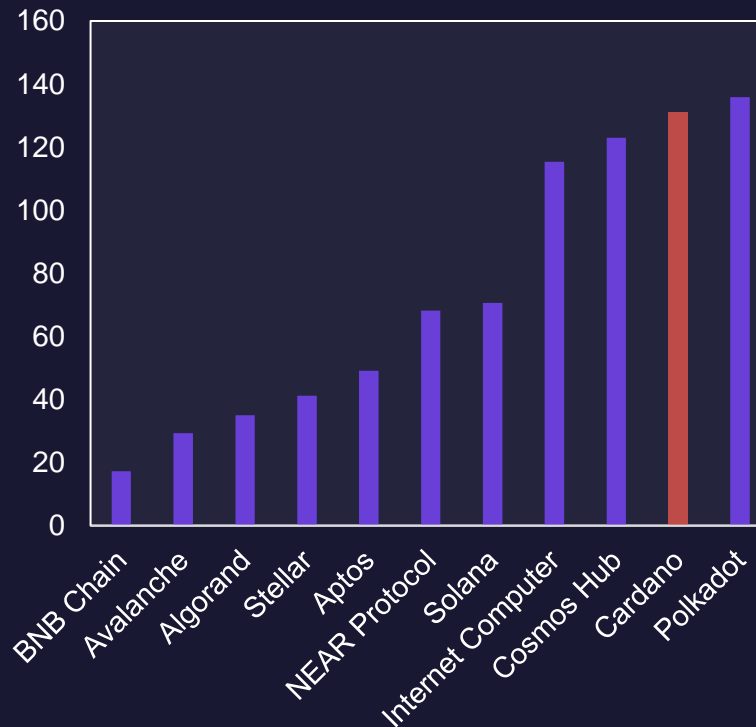
# Committed Existing Developer Base

- Cardano has an established base of active developers who committed the most code to Github among L1's\* in the past 365 days.
- In the last 30 days\*, Cardano trails only Ethereum and Polkadot in active daily developers, boasting over 120.
- Although Cardano has a solid core of active developers, growth was stagnant through most of 2022 before sharply declining in Q4 in the wake of the FTX collapse. Renewed signs of life have been seen in 2023, climbing back above 140 developers.

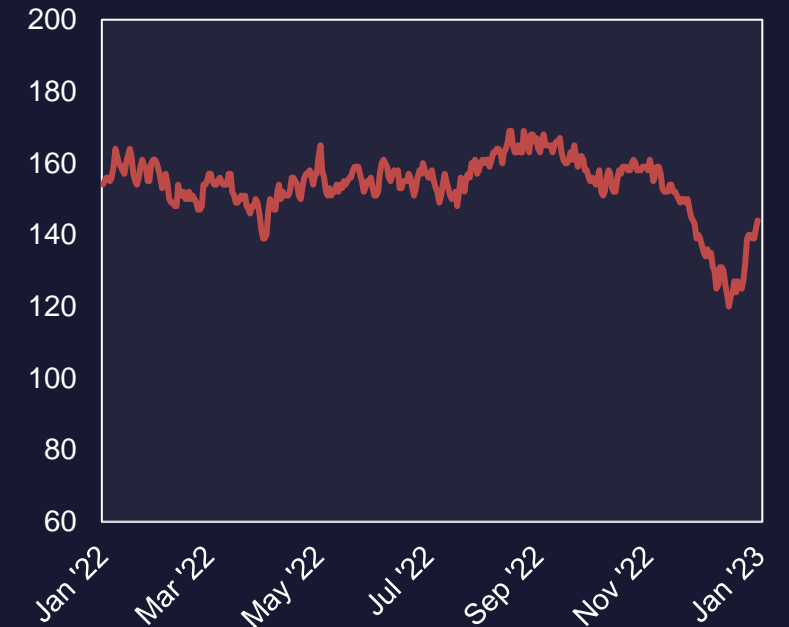
L1 Total Code Commits (365 Days)



L1 Active Developers (30 Day Avg)



ADA Active Developers



\*Data includes L1 networks tracked by Token Terminal with a market cap over \$1.5 billion as of 2/1/23

Source: FS Insight, TokenTerminal



# Cardano Ecosystem

- Cardano has an ecosystem of over 700 projects across various verticals, providing users with the required infrastructure to explore multiple avenues of interest.



# Highlighted Projects: JPG Store

- JPG Store is ranked the #1 dApp in the Cardano ecosystem by DappRadar and #40 for all crypto dApps.
- No other Cardano NFT marketplace has rivaled JPG Store in adoption. The next most popular NFT marketplace is CNFT, and JPG Store dwarfs CNFT in all KPIs.

## Highlights

- \$18.6 million in royalties paid
- 409.4 million ADA in trading volume
- 251,600+ unique wallets

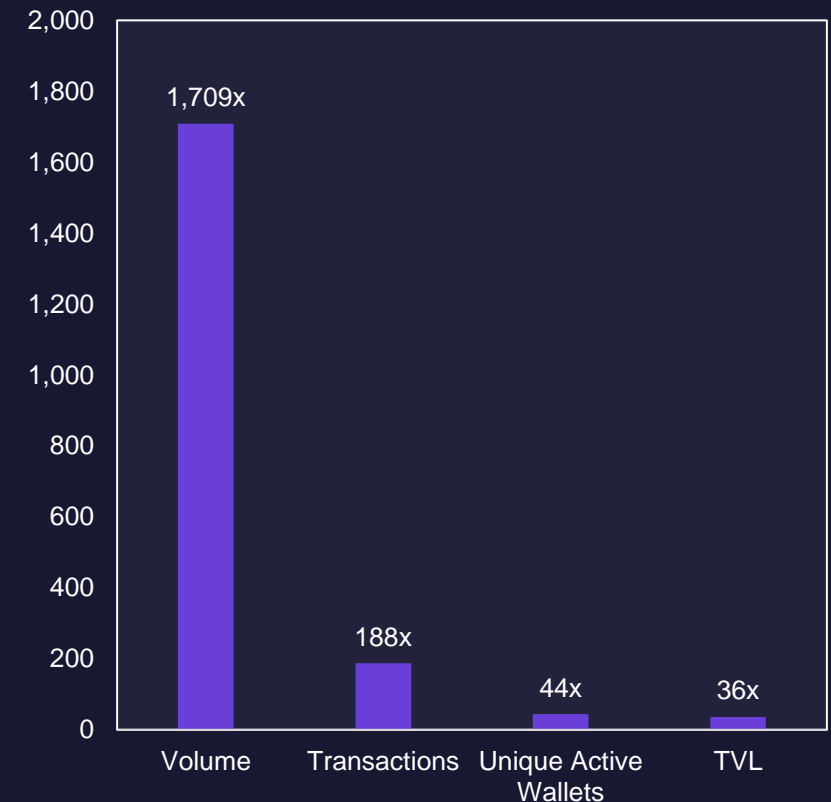
## Platform Fees

- 2% commission on all NFT sales
- ~1.5 ADA to list an asset on the smart contract
- ~1.2 ADA returned when asset is delisted
- ~0.25 ADA to update assets that are listed on the smart contract

## Top NFT Projects on JPG Store

Rank	Project	Total Volume (Millions ADA)
1	SpaceBudz	41.3
2	Pavia	32.2
3	Clay Nation	32.0
4	The Ape Society	27.9
5	Boss Cat Rocket Club	24.4
6	Chilled Kongs	18.6
7	Boss Cat Rocket Parts	14.4
8	Pitches at Clay Nation	11.7
9	DEADPXLZ	11.7
10	Cornucopias	11.4

## JPG Store vs CNFT



# Highlighted Projects: Atala Prism & IAMX

- IOG is focused on creating a secure digital identity for people worldwide with multiple projects utilizing the Cardano blockchain network, including their own Atala Prism project as well as IAMX.

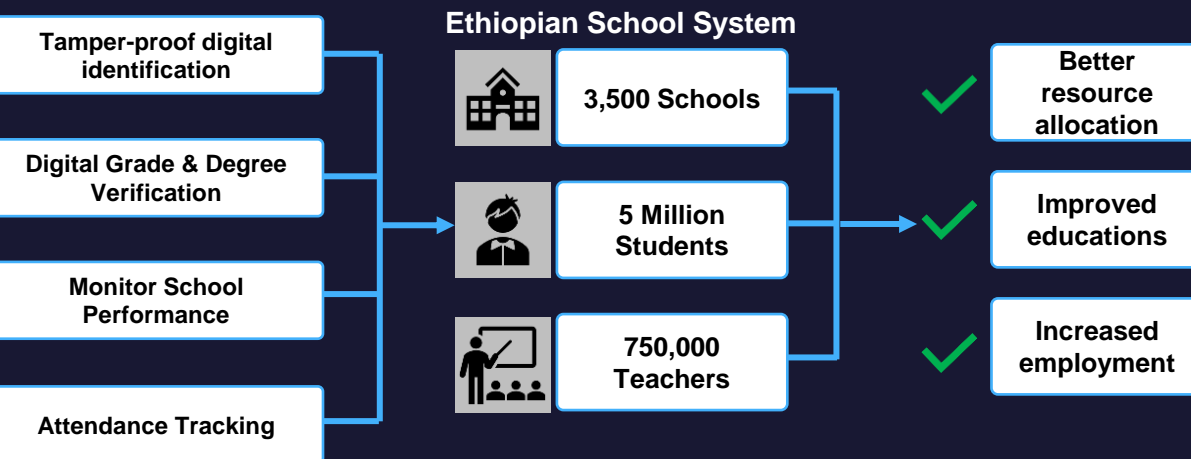
## Atala Prism

### Overview

- Atala PRISM is a decentralized identity & record keeping solution with the goal of digitizing services in developing geographies.
- Built on Cardano, the platform is highly customizable depending on the use case and user base, as well as highly secure and scalable.

### Use Case

- Atala PRISM is a key component of Ethiopia's Digital Transformation strategy. The platform is first being implemented in the country's education system of 5 million students and is expected to provide a host of benefits.



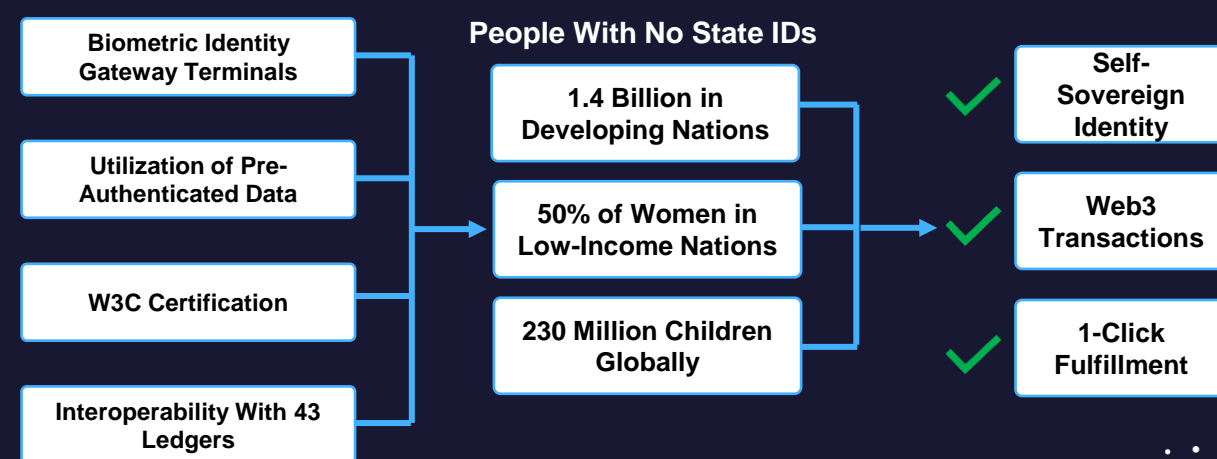
## IAMX

### Overview

- IAMX is an SSI platform being built on the Cardano Network that uses biometrics and blockchain technology to issue digital identities and allow users to maintain full custody of personal data.
- IAMX aims to leverage Cardano to become the most secure SSI platform in the world.

### Use Case

- A considerable portion of the global population lacks a formal state identity, especially across developing and low-income nations.
- IAMX wants to target the global eCommerce market, recognizing the market potential for digital wallet shopping and payments.



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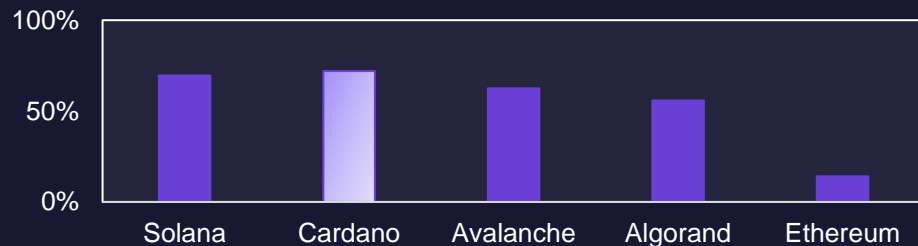
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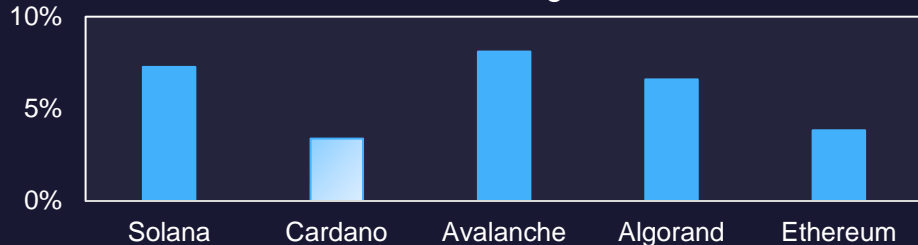
# Staking Overview

- Cardano's Proof-of-Stake (PoS) consensus mechanism, Ouroboros Praos, allows users to participate in block production by operating stake pools on their own or delegating to existing stake pools in exchange for staking rewards.
- Cardano currently boasts one of the highest staking participation rates amongst L1s with over 70% of the 35 billion circulating token supply committed to a staking pool.
- After inflation, the current real yield for delegators is 1-3% depending on fees charged by the pool operator.

L1 Staking Participation Rates



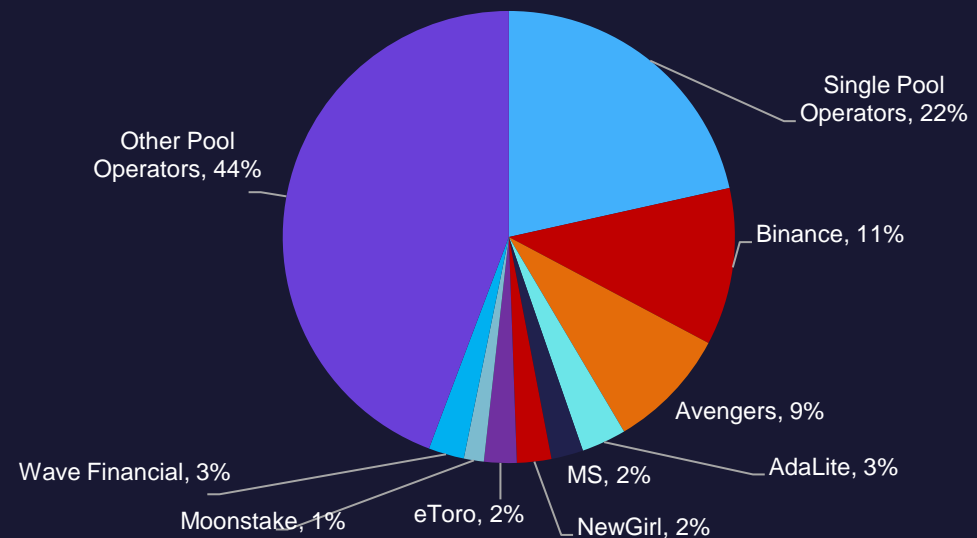
L1 Nominal Staking Yields



~3,000  
Total Pools

~1.2 Million  
Staking Addresses

ADA Staking Pool Distribution\*



The largest individual staking pools are operated by entities with significant ADA holdings like exchanges, wallets, and investment firms that generate income-type yield on client assets.

\* Data as of June 2022





# Cardano Network Metrics

- After a rapid rise in FDV to nearly \$100 billion in Q3 of 2021, Cardano has fallen significantly to \$11 billion at the end of Q4 2022. The sharp decline was largely attributable to poor macroeconomic conditions throughout 2022.
- Average daily transaction count may have bottomed in Q3 2022 as Cardano saw a 13% increase in Q4 2022, but this metric is still well below its highs of roughly 125 million daily transactions in Q1 of 2022.

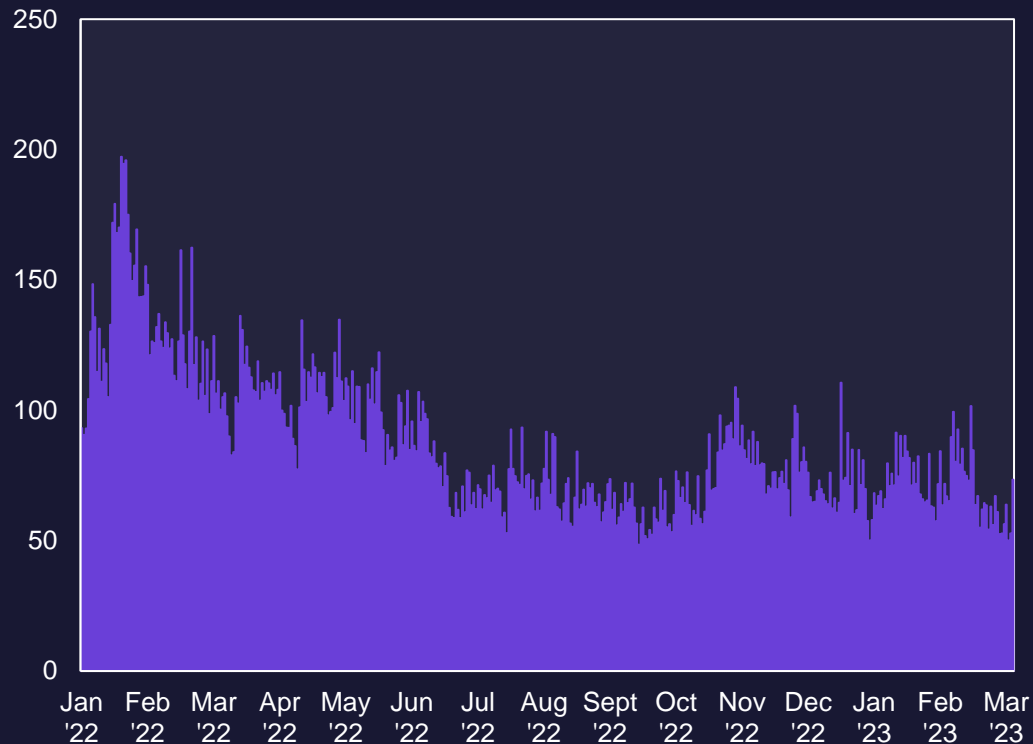
Quarter End	Q3 2020	Q4 2020	Q1 2021	Q2 2021	Q3 2021	Q4 2021	Q1 2022	Q2 2022	Q3 2022	Q4 2022
ADA Price (\$)	\$0.10	\$0.18	\$1.19	\$1.38	\$2.11	\$1.31	\$1.14	\$0.45	\$0.44	\$0.25
% Change	21%	80%	556%	16%	53%	-38%	-13%	-61%	-3%	-44%
Circulating Supply (MM)	31,635	31,812	32,010	32,188	32,397	32,910	33,123	33,469	33,625	33,870
% Change	2%	1%	1%	1%	1%	2%	1%	1%	1%	1%
Market Cap (\$MM)	\$3,199	\$5,780	\$38,180	\$44,454	\$68,391	\$43,169	\$37,915	\$15,120	\$14,807	\$8,608
% Change	24%	81%	561%	16%	54%	-37%	-12%	-60%	-2%	-42%
FD Supply (MM)	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FD Market Cap (\$MM)	\$4,550	\$8,176	\$53,673	\$62,147	\$94,997	\$59,028	\$51,510	\$20,330	\$19,709	\$11,057
% Change	21%	80%	556%	16%	53%	-38%	-13%	-61%	-3%	-44%
Avg Daily Active Addresses	13,917	13,121	64,679	88,983	104,322	169,506	157,248	88,722	64,176	68,262
% Change	62%	-6%	393%	38%	17%	62%	-7%	-44%	-28%	6%
Avg Daily Txn Count	5,666	5,885	25,480	40,542	56,489	113,682	125,674	94,082	66,798	75,440
% Change	60%	4%	333%	59%	39%	101%	11%	-25%	-29%	13%
Total Fees (\$MM)	\$0.0	\$0.0	\$0.5	\$1.2	\$2.4	\$3.9	\$4.3	\$2.3	\$1.1	\$0.8
% Change	151%	8%	2598%	159%	104%	61%	9%	-47%	-54%	-28%
Total Value Transferred (\$MM)	\$0.10	\$0.10	\$0.70	\$0.60	\$1.20	\$0.90	\$2.00	\$1.90	\$0.7	\$0.3
% Change	248%	-56%	1033%	-5%	88%	-27%	136%	-4%	-62%	-52%
Average TVL (\$MM)	NA	NA	NA	NA	NA	NA	\$165	\$215	\$124	\$79
% Change	NA	NA	NA	NA	NA	NA	NA	30%	-42%	-36%



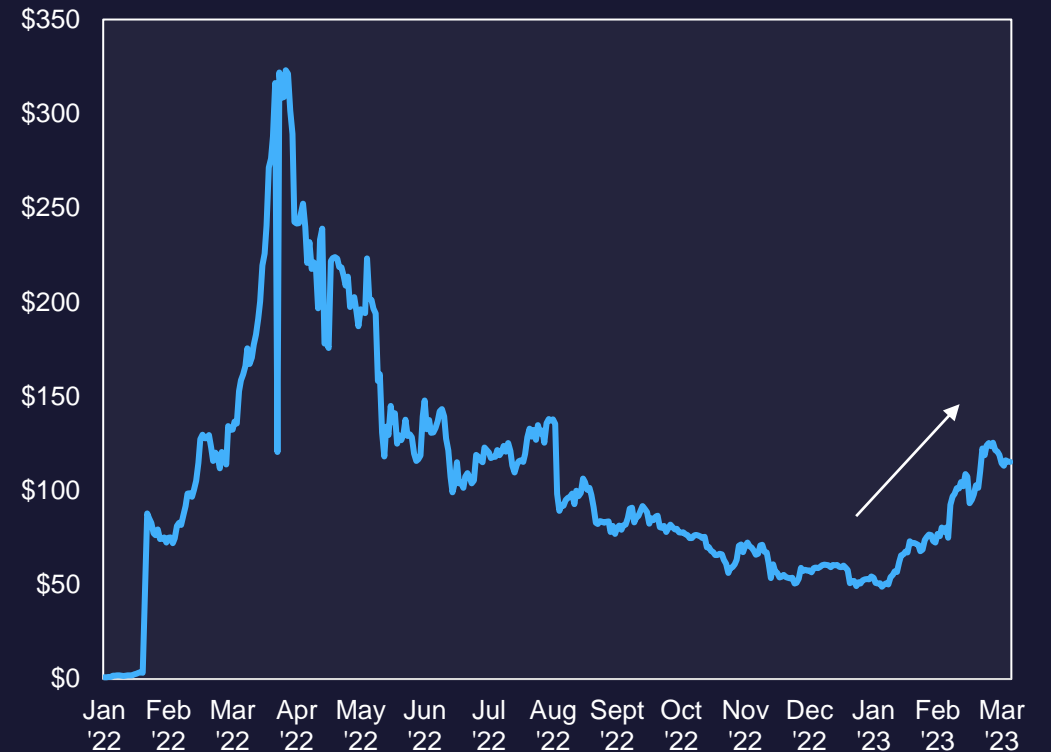
# Cardano Network Metrics

- Network activity broadly declined in line with token prices throughout 2022. Daily Txn Count and TVL saw significant declines.
- 2023 has started on a brighter note as Cardano TVL has increased 135% YTD, comparing favorably to Ethereum's 29% growth over the same period.

ADA Daily Tx Count (000's)

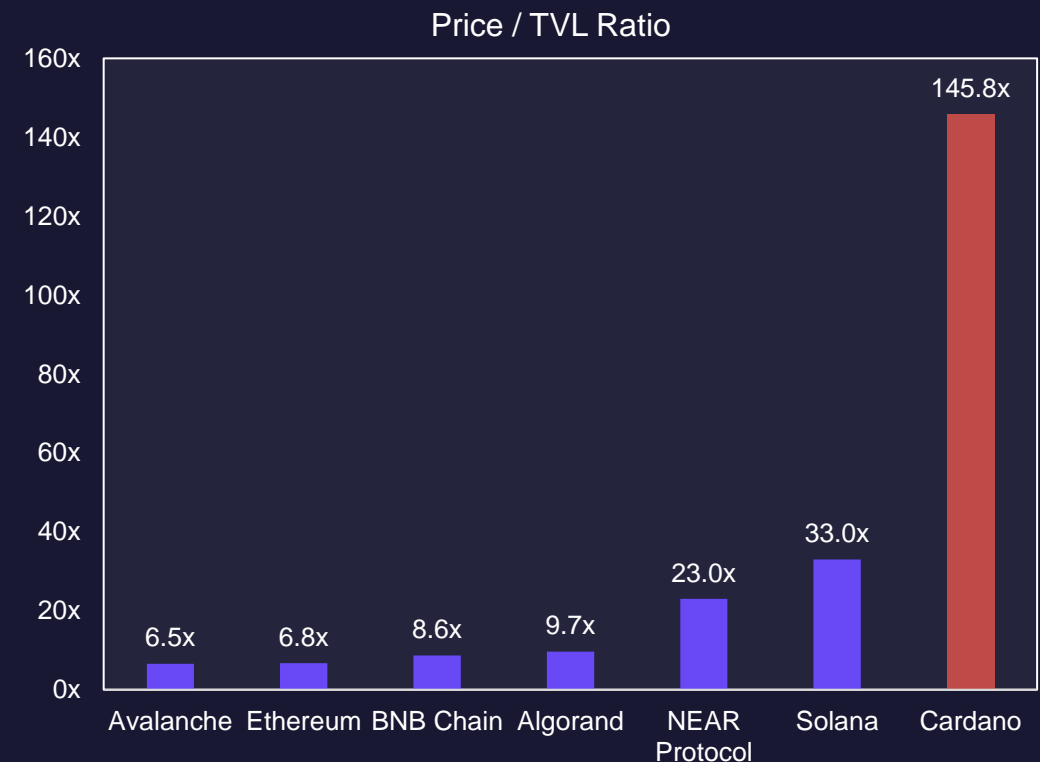
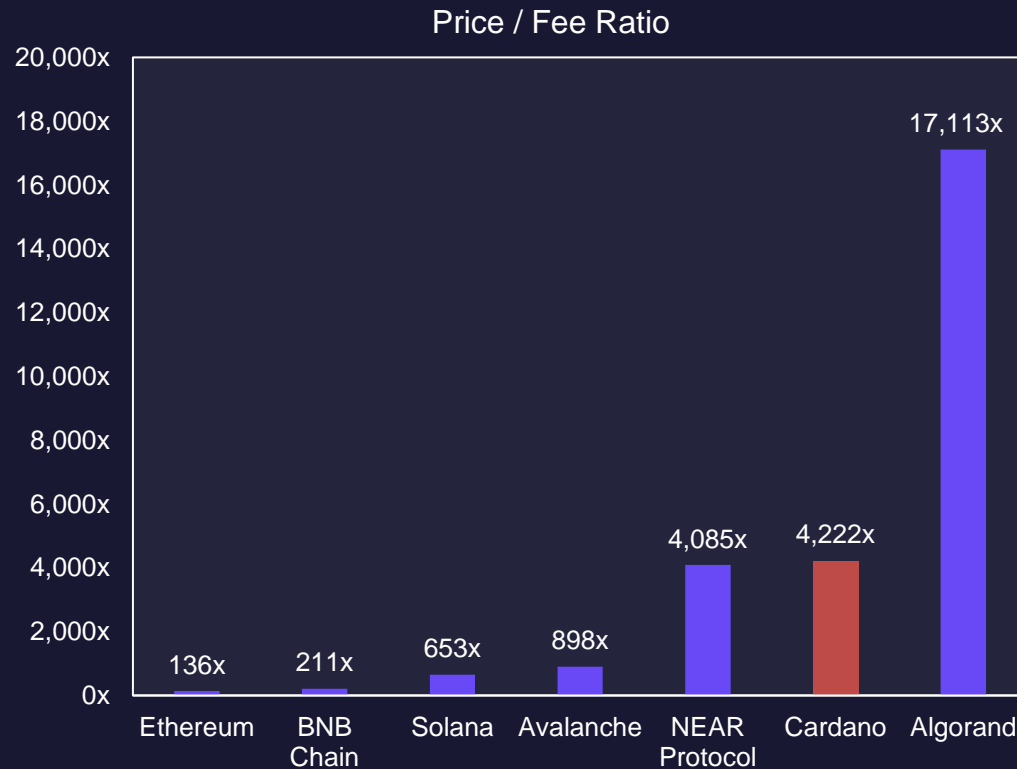


TVL (\$ Mil)



# Valuation Metrics

- Below, we calculated multiples of price/fees (P/F) and price/total value locked (P/TVL) among competing L1 blockchains. P/F is calculated using the non-fully diluted market cap divided by the annualized daily fees over the previous 30 days.
- While we acknowledge the limitations of TVL as a reliable valuation metric, we feel it does provide directional insight on how frothy a token's price is relative to the economic value stored in each ecosystem.
- Based on the latest data, Cardano ranks toward the higher end of both multiple ranges. Elevated trailing multiples demonstrate the high expectations the market is putting on future growth and development of the network.



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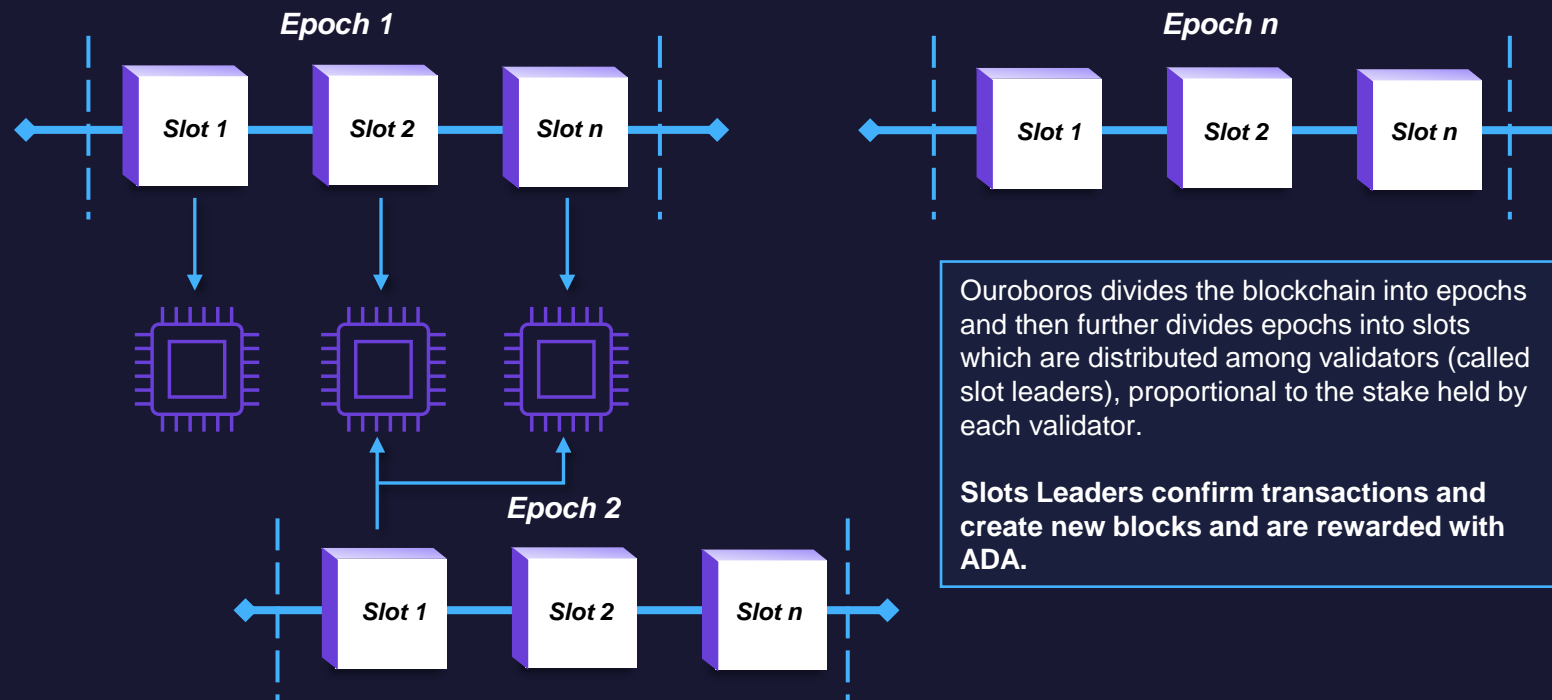
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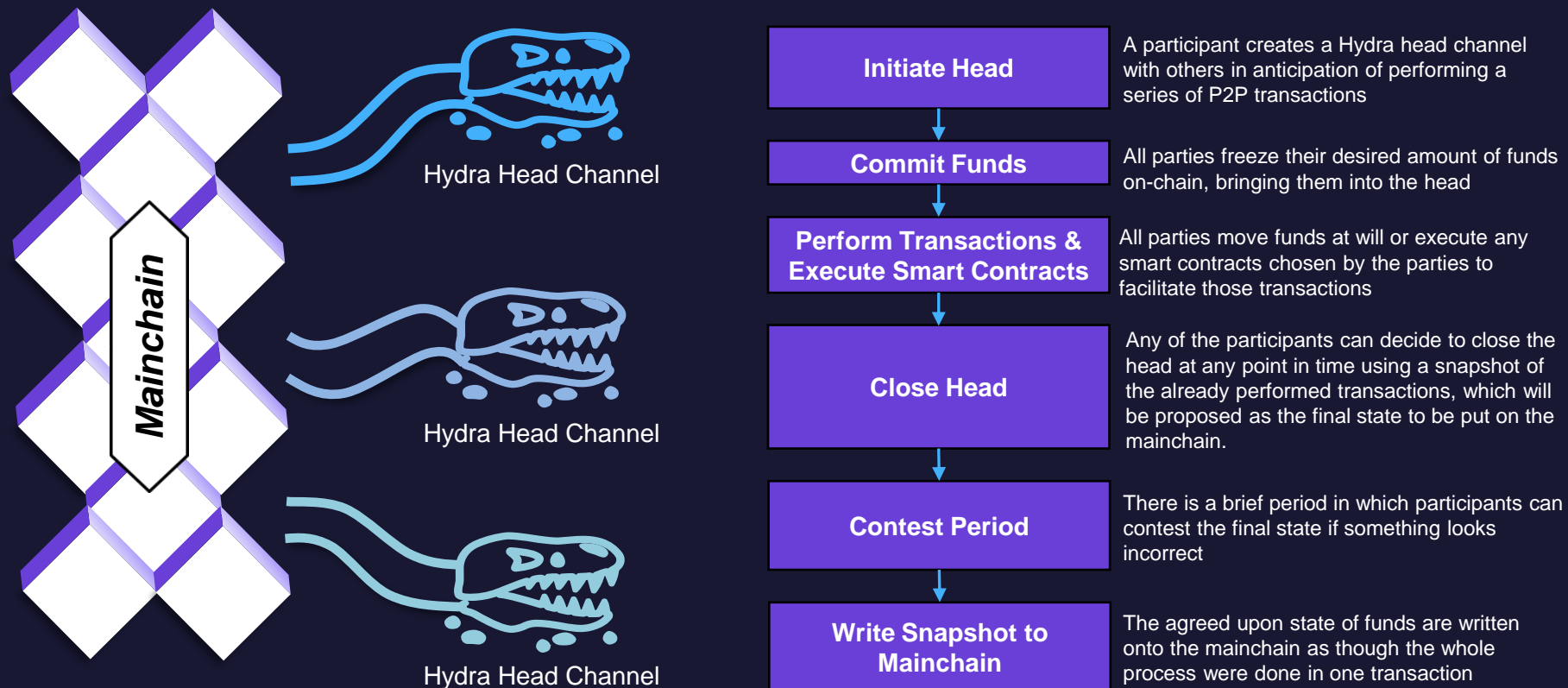
# Cardano Employs Ouroboros Consensus

- Ouroboros is a proof-of-stake protocol based on peer-reviewed research
- Ouroboros organizes blocks into time slots, which are distributed randomly such that each node validates a number of blocks proportional to the ADA staked. All nodes validate every block.
- Cardano does not require computationally-intense block mining as in Proof-of-Work blockchains, nor does it require slashing. Instead, the protocol's reliability is achieved through random leader selection. Ouroboros Praos has been deemed provably secure via peer-reviewed research.



# Hydra Allows For Off-Chain Transactions

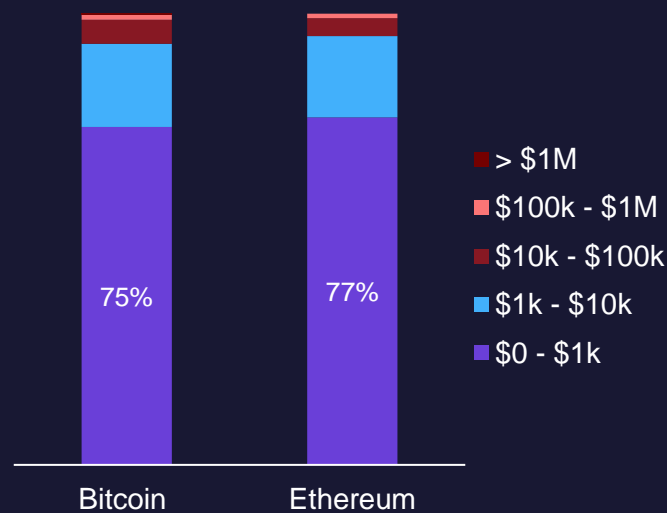
- Hydra is a layer 2 scaling solution that enables peer-to-peer microtransaction throughput by allowing users to perform a series of actions off-chain and move only the final state of those actions back on-chain.
- Hydra uses isomorphic state channels, meaning every head channel takes on the same exact properties of the mainchain. This allows for on-chain security in off-chain transactions, seamless closing of head channels, and smart contracts written on the mainchain to be applied within Hydra heads.



# Hydra Alleviates Network Congestion

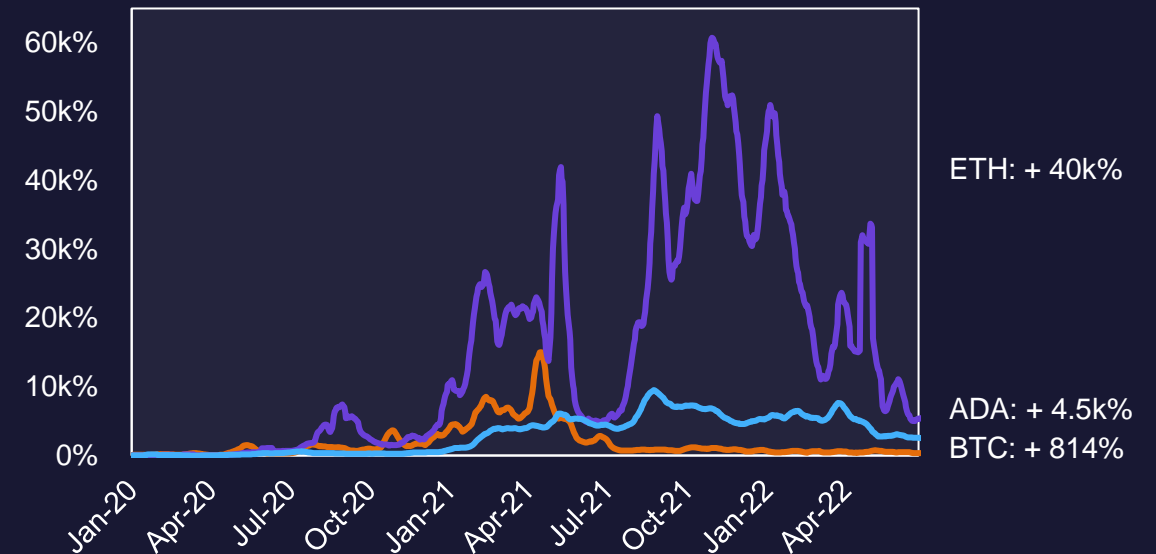
- Moving peer-to-peer payments off-chain will likely free up a sizeable portion of available computing resources.
- Hydra will allow dApp developers to choose the level of data availability and storage required for their application. Applications that prioritize low transaction fees and minimal latency will run through Hydra, while dApps that require a more granular level of verification and security will remain on the mainchain.

Distribution of Transactions Based on Size



Using network activity on Ethereum and Bitcoin as a proxy for the distribution of txn sizes on Cardano, we can estimate that approximately 75% of transfers occurring on Cardano are likely small (<\$1k) peer-to-peer payments.

Increase in Transaction Fees (%)

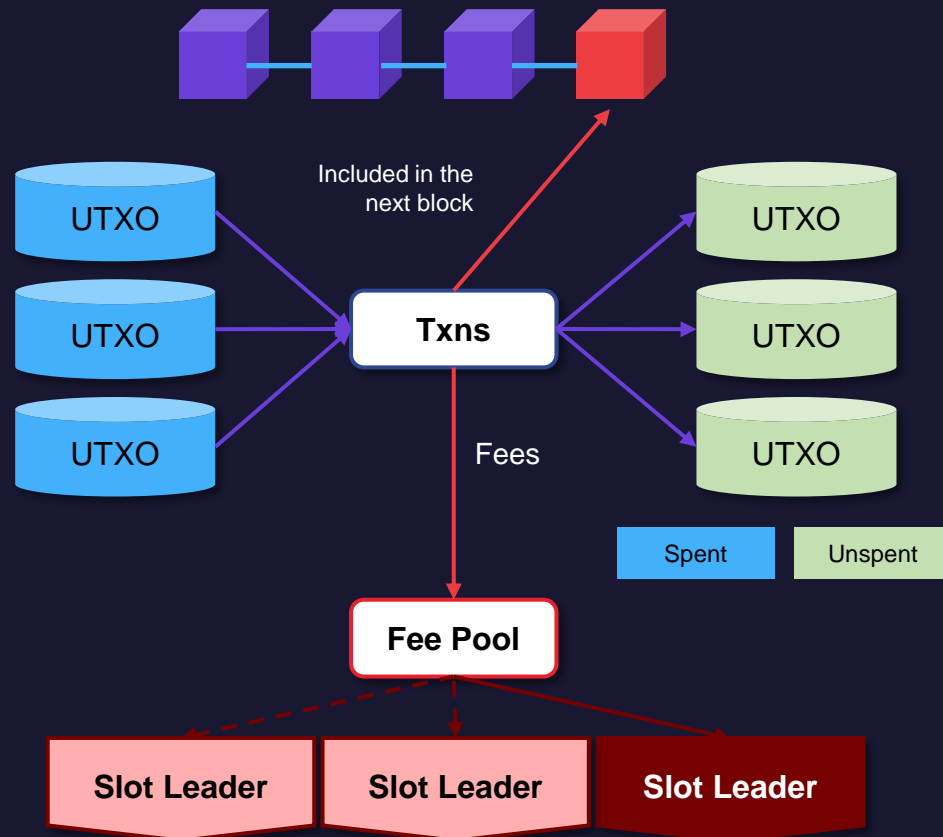


Demand for Ethereum's smart contract capabilities and proven security model has pushed gas fees to non-negligible amounts. Cardano is not yet seeing the same pressure on the network's computation power due to the nascency of smart contracts on Cardano, but Hydra is expected to prevent that pressure from occurring.



# Cardano Transaction Fee Design in EUTXO Model

- Cardano employs an Extended Unspent Transaction Output (EUTXO) accounting model (as opposed to an account-based model like Ethereum) for its ledger. This combines the structural simplicity of the UTXO model with the ability to execute smart contracts.
- Upper bounds on stake reward proportionality favors fair distribution and decentralization ethos.



- 1 **Fee in ADA / Byte**  
*This covers the computing and storage cost*
- 2 **DDoS Protection**  
*Dummy transactions cost attackers a significant amount of money.*

$$Fee_{Tx} = 0.000044 * (n_{Bytes}) + 0.155381$$

- To incentivize decentralized staking, stake pools have a maximum limit before they no longer receive greater rewards. That limit is at  $1/k$ , where  $k = 500$  as of writing.
- Fees are held in a pool until the end of every epoch and then distributed amongst the nodes that were elected as slot leaders at a proportion equal to the portion of blocks created by each node





# Cardano Transaction Fee Design in EUTXO Model (Cont.)

- Advantages of the EUTXO model are greater cost predictability and the ability to process multiple transactions in parallel. Cardano is written in Haskell, a functional programming language, which enables increased precision and traceability compared to object-oriented languages like Solidity or Rust.
- At the base layer, script execution cost is comprised of the current cost of each CPU & memory unit, as well as the transaction size. Additional scripts within transactions will add additional execution costs.

## Key Script Txn Fee Inputs & Examples

**1** **On-chain Transaction Size (Bytes)**  
*The size of a transaction varies - around 300 bytes for a simple transaction and scripts ranging from ~4,000-8,000 bytes*

**2** **Number of Computational Steps (CPU)**  
*1 step is equivalent to 1 picosecond of execution time. Most scripts consume less than 1,000,000,000 steps*

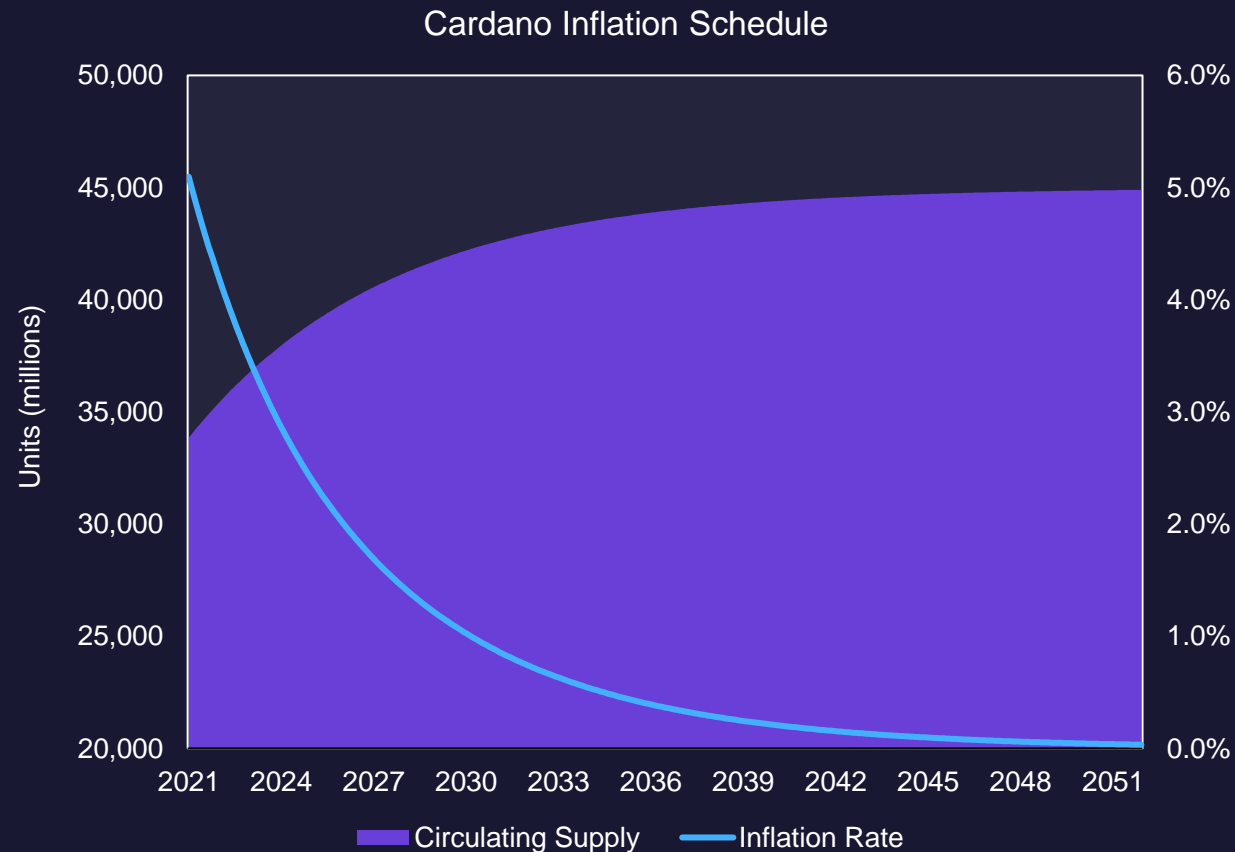
**3** **Number of Memory Units (Bytes)**  
*Memory units represent the number of bytes that the script allocates. Most scripts should use less than 1,000,000 bytes (1 MB)*

Example Transactions	Txn Size (Bytes)	CPU	Memory (Bytes)	Estimated Fee (ADA)
Simple Transaction (sending ADA only)	300	0	0	0.17
Plutus AlwaysSucceeds Script	340	1,624,000	160	0.17
Plutus Minting Script	3,400	500,000,000	1,400,000	0.42
Complex Plutus Script	8,192	2,000,000,000	1,000,000	0.72
Maximum Script Cost	16,384	10,000,000,000	10,000,000	2.17



# Cardano Distribution Schedule

- Monetary expansion will be the main source of rewards for operators and delegators early on, but this will gradually be replaced by transaction fees detailed in the previous slide as inflation converges to null.

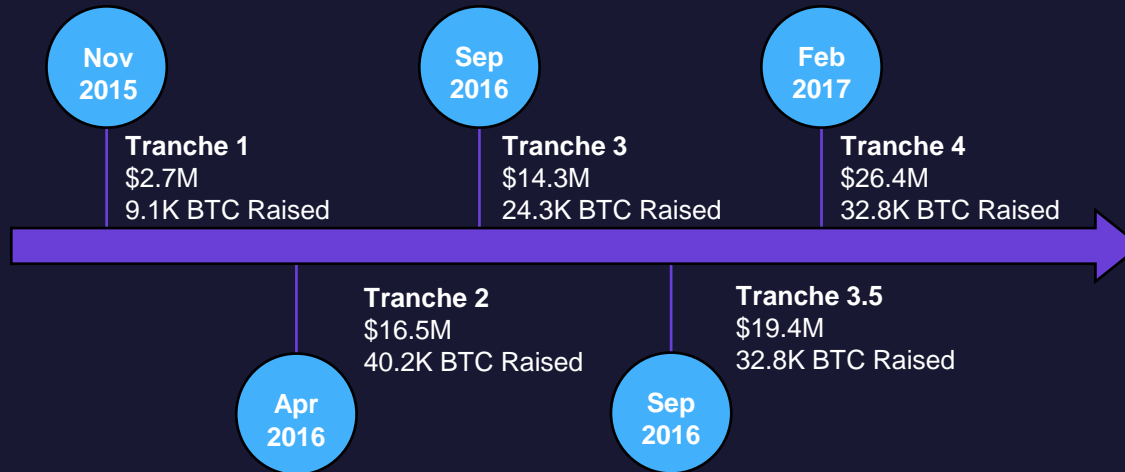


- Cardano's inflation rate is a function of the balance in the reserves and participation in staking.
- Given the formula above, the reserves will never be completely empty. Instead, the rate of inflation asymptotically approaches zero.
- This makes ADA disinflationary, similar to the inflation rate of Bitcoin, which halves every four years.



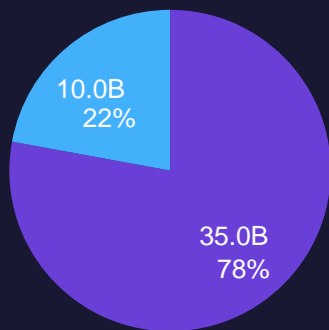
# Cardano Funding Rounds

- Cardano has only raised external funding from a series of ICO rounds, separating it from well-funded competing Layer-1s that have risen to popularity in 2021 such as Solana and Avalanche.



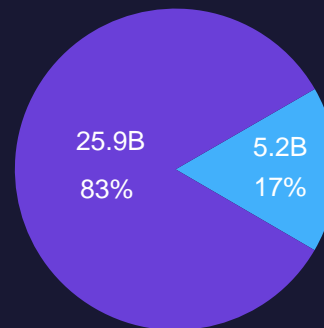
- Cardano raised \$76.4M for over 5 public funding rounds from 2015 – 2017.
- Cardano distributed vouchers for 25.9B ADA in a series of public token sales from September 2015 to January 2017. Through Cardano's native Daedalus wallet, participants could redeem vouchers for actual ADA tokens.
- Three entities supporting Cardano's development received 5.2B ADA in total, with the most significant recipient being IOG (48%).

Cardano Distribution to Date



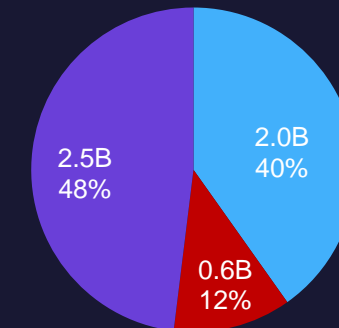
■ Distributed Tokens ■ Ongoing Issuance

Initial Token Distribution



■ Founders & Projects ■ Investors

Founders & Project Breakdown

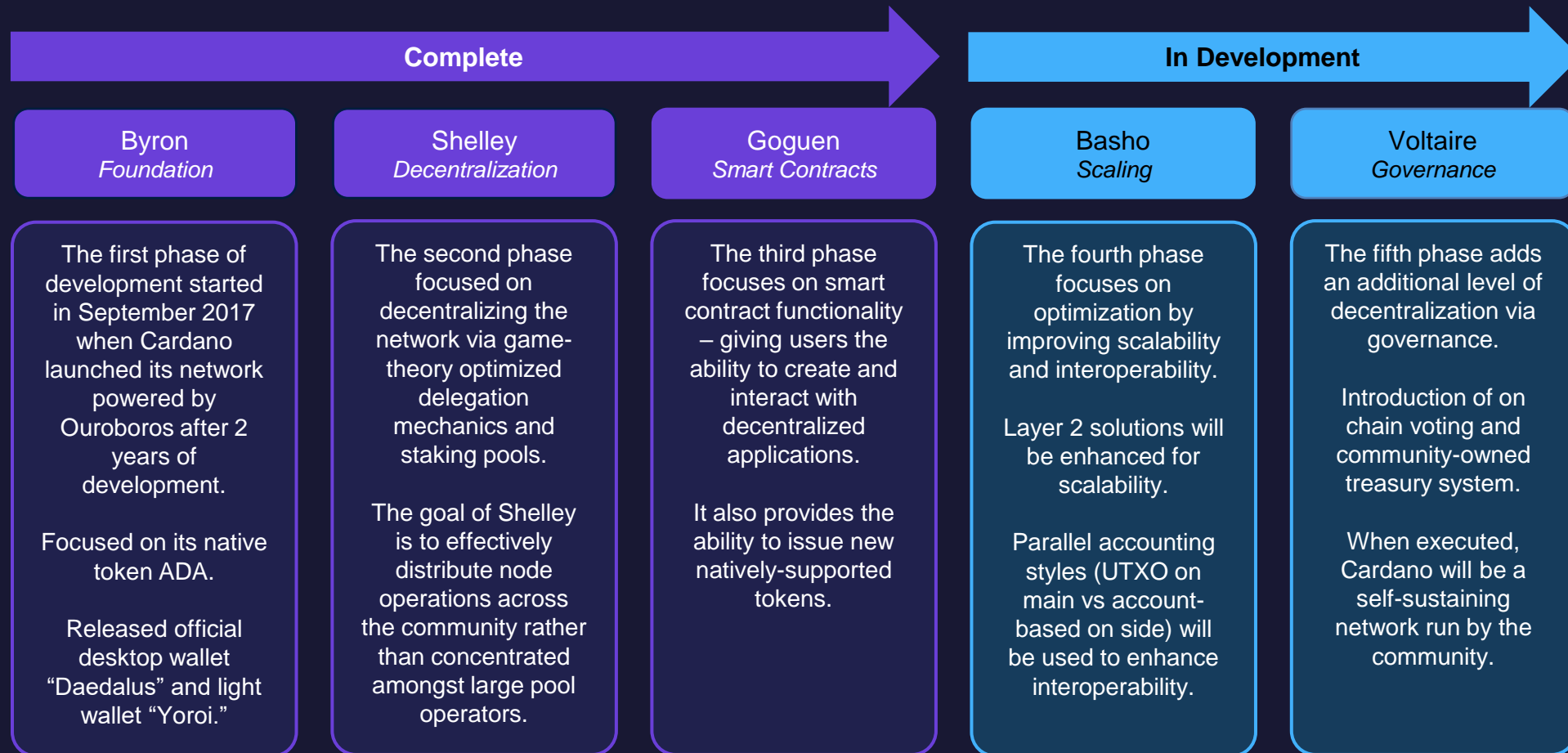


■ Emurgo ■ Cardano Foundation ■ IOG



# Development Roadmap

- Cardano has five “Eras” in their roadmap, from building blocks to governance.
- Basho and Voltaire are still in development, but Cardano is making strides with their Hydra scaling solution, an SECP (Valentine) upgrade allowing for increased cross-chain interoperability on 2/14/23, and work towards implementing on-chain governance.



# Disclosures

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