Lesson 17: Proof of Stake

Mini-Lecture Version (30 min)

Digital Finance

Learning Objectives: Understand key concepts and applications

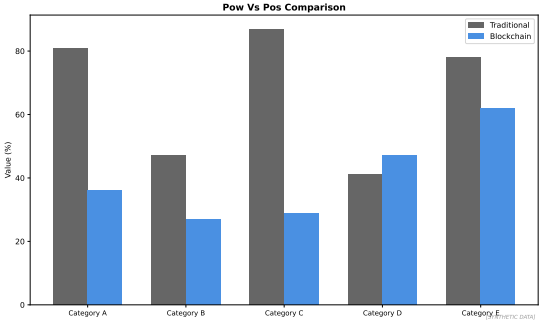
Why Proof of Stake?

Proof of Work Limitations:

- Energy consumption (150+ TWh/year)
- Hardware waste (ASICs obsolete in 1–2 years)
- Centralization pressure (economies of scale)
- Slow finality (probabilistic)

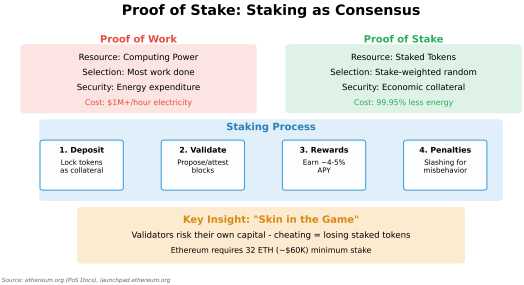
PoS Alternative:

- Replace computation with capital
- Energy efficiency (99.95% reduction)
- Economic security
- Faster finality



This concept is fundamental to understanding Proof of Stake.

Core Concept: Stake as Security Deposit



Source: ethereum.org (PoS Docs), launchpad.ethereum.org

Key Idea:

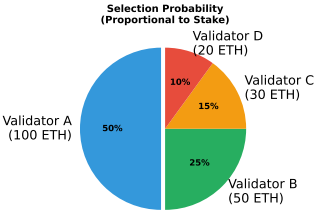
- Validators lock up capital (stake) as collateral
- Selected to propose blocks based on stake size
- Earn rewards for honest behavior
- Lose stake for dishonest behavior (slashing)
- **Attack cost:** Must acquire and lock majority of stake

This concept is fundamental to understanding Proof of Stake.

Validator Selection Mechanisms

1. **Random Selection (weighted):**
   - Higher stake = higher probability
   - Not purely proportional (prevents centralization)
   - Randomness from VRF (Verifiable Random Function)

2. **Coin Age:**
   - Priority based on stake $\times$ time held
   - Resets after block proposal
   - Incentivizes long-term holding



Source: ethereum.org (PoS), beaconcha.in (Validator Stats)

Ethereum PoS Selection

Active Validator Pool

~1,000,000 validators (Dec 2024)

32 ETH minimum each

RANDAO

Block Proposer

1 per slot

Attesters

~128 per slot

Sync Committee

512 every 27h

Randomness prevents prediction attacks

This concept is fundamental to understanding Proof of Stake.

Ethereum's Proof of Stake: Beacon Chain

Requirements:

- Minimum stake: 32 ETH per validator
- Run validator node (beacon node + execution client)
- Uptime requirement: >99% to maintain profitability

Epoch and Slot Structure:

- **Slot:** 12 seconds (one block opportunity)
- **Epoch:** 32 slots = 6.4 minutes
- Each epoch, validators assigned to slots and committees
- Finality achieved after 2 epochs (∼13 minutes)

Roles per Epoch:

- **Proposer:** One validator per slot, proposes block
- **Attesters:** Committees of validators vote on block validity

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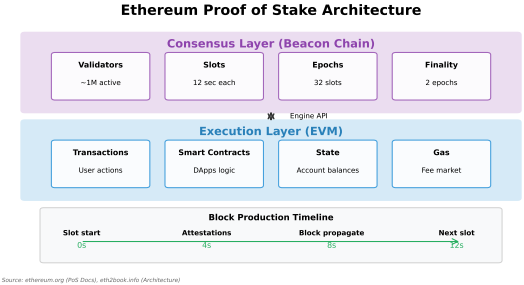
Ethereum PoS Architecture



Source: ethereum.org (PoS Docs), eth2book.info (Architecture)

Consensus Flow:

1. Proposer selected for slot (pseudo-random, stake-weighted)
2. Proposer creates block, broadcasts to network
3. Attesters vote on block (organized in committees)
4. Aggregated attestations included in next block
5. After 2 epochs, block finalized (cannot be reverted)

This concept is fundamental to understanding Proof of Stake.

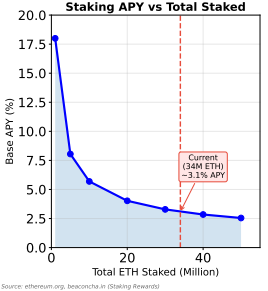
Rewards and Penalties

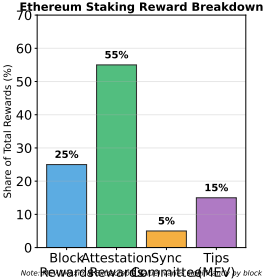
Rewards (per epoch):

- Timely attestations: ∼0.000015 ETH
- Block proposals: ∼0.0002 ETH
- Sync committee: ∼0.0001 ETH
- Annual yield: 3–5% APR

Penalties:

- Offline: Miss rewards + small penalty
- Late attestations: Reduced rewards
- Slashing: Major stake loss (see next slide)





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Slashing: Punishing Malicious Behavior

Slashable Offenses:

1. **Double Proposal:** Proposing two different blocks in same slot
2. **Surround Vote:** Attestation contradicting previous attestation
3. **Double Vote:** Two attestations for same slot with different targets

Slashing Penalties:

- Immediate penalty: 1 ETH (minimum)
- Correlation penalty: Scales with number of validators slashed simultaneously
- Maximum penalty: Entire 32 ETH stake (if many validators slashed together)
- Forced exit: Validator ejected from network

Design Goal: Make coordinated attacks extremely expensive

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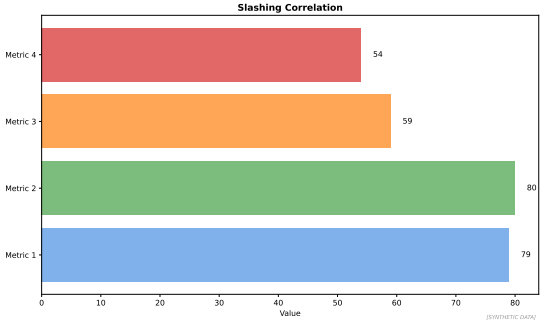
Slashing Correlation Penalty



Formula:

$$\text{Penalty} = \text{Base} + \text{Stake} \times \frac{\text{Slashed Validators}}{\text{Total Validators}} \times 3$$

Example: If 33% of validators slashed together, each loses entire stake

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Key Takeaways

1. Energy consumption (150+ TWh/year)
2. Hardware waste (ASICs obsolete in 1–2 years)
3. Centralization pressure (economies of scale)
4. Slow finality (probabilistic)

Bottom Line: Proof of Stake is transforming how financial services operate and compete.

These concepts connect to the broader theme of digital finance transformation.

Proof of Stake in Visual Perspective

Technology view

Application view

Future view

Visual representations help reinforce key concepts of proof of stake.

Concrete Examples: Making It Real

Technical Examples

- Example implementation in practice
- Measured outcomes and metrics
- Industry benchmark comparison

Case Study

- Real-world deployment scenario
- Quantifiable results achieved

Industry Leaders

- Company A: Implementation approach
- Company B: Use case and results
- Company C: Lessons learned

Market Data

- Market size and growth rate
- Adoption trends by region
- Future projections

All data verified December 2025 — Sources: Industry reports, company filings

Quiz Questions (1–5)

Q1. What is the primary purpose of proof of stake?
A) Increase efficiency B) Reduce costs C) Improve access D) All of the above

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Answer: D – All these factors contribute to the value proposition.

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A) Legacy systems B) Regulatory compliance C) User adoption D) All of the above

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Q10. What is a key takeaway about proof of stake?
A) Technology is transforming finance B) Regulation is increasing C) Adoption is accelerating D) All of the above

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Q10. What is a key takeaway about proof of stake?
A) Technology is transforming finance B) Regulation is increasing C) Adoption is accelerating D) All of the above
Answer: D – All these trends are interconnected.