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The Green Evolution of Ethereum

Ethereum's Sustainability Journey

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Beatrix Marosvölgyi
Matthias Hafner

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Agenda


Calculation of the resource consumption


POW Ethereum


The Merge and POS Ethereum


Dencun upgrade


Discussion

Calculation of the Resource Consumption

Life-cycle assessment (LCA)

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Life-cycle assessment: Standard method to measure environmental impacts associated with a product's life-cycle.

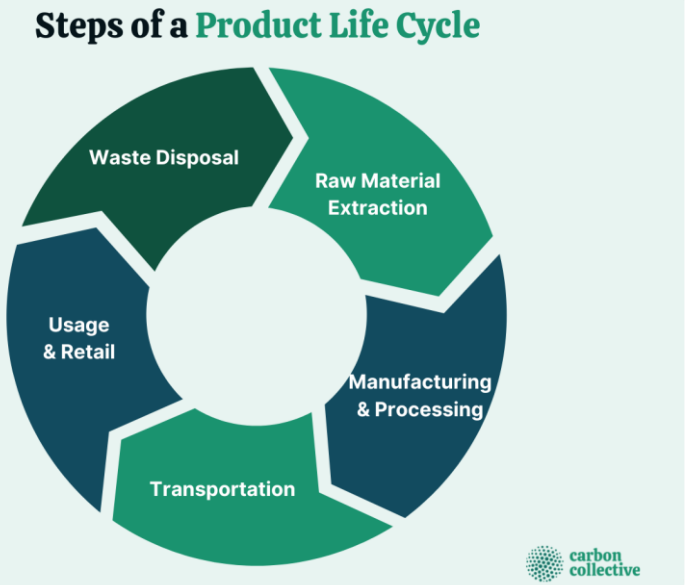
Environmental impacts connected to inputs and emissions to soil, air, water…:

- Energy consumption (MJ)
- Greenhouse gas (GHG) emissions (CO_2 eq.)
- Water usage (m^3)
- Waste generation (kg)

The most studied impacts of blockchains

The least studied impacts of blockchains

	Consensus M.	Redundancy
Hardware	POW → POS	L2 & Sharding
Software	POW → POS	L2 & Sharding



Source: carboncollective.co

It is fairly difficult to conduct a complete life-cycle assessment of blockchains due to their decentralized nature and lack of data.

POW Ethereum

Understanding the hash (technical background)

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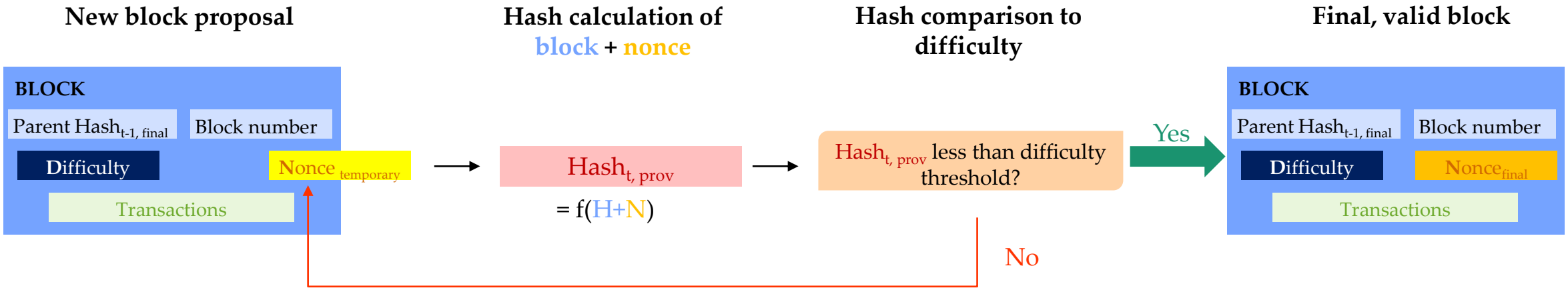

Nonce:
The nonce is an arbitrary string.

Hash function:
Keccak-256, is POW-Ethereum's hash function. It is a cryptographic function, which i.e. translates an input into a unique and deterministic set of characters.

Hash:
The output of the cryptographic function.

Terahash/s:
The network difficulty measured in terahash/second gives us a clue of how many calculations are invested per second to find the correct nonce. This is the key to a POWs energy consumption.

New block:
Miner communicates the Block with the whole network, they validate it and it is added to the blockchain.

POW Ethereum

Results

Upper figure: Network difficulty of Ethereum in TH/s

Bottom figure: Annualized electricity consumption of POW-Ethereum in TWh

→ Almost identical pattern

Other source of energy consumption in POW-Ethereum besides mining:
Smart contracts BUT
Relative to mining, negligible amount.

Blockchain	Annualised electricity consumption (GWh)	Annualised carbon footprint (t CO_2 eq.)	Annualized number of TX
Ethereum pre-Merge	22'900 – 21'410	11.02 Mio. – 10.26 Mio.	1'751'094'429 (implied by gas)
Bitcoin	89'440	45.32 Mio.	74'989'250

In POW, with increasing hardware efficiency and popularity, the network difficulty is increasing and thus the number of calculations constantly grows.

Network difficulty of Ethereum in TH/s.

Source: etherscan.io

Annualized electricity consumption of POW Ethereum in TWh.

Source: indices.carbon-ratings.com

The Merge and POS Ethereum

The effect of the Merge

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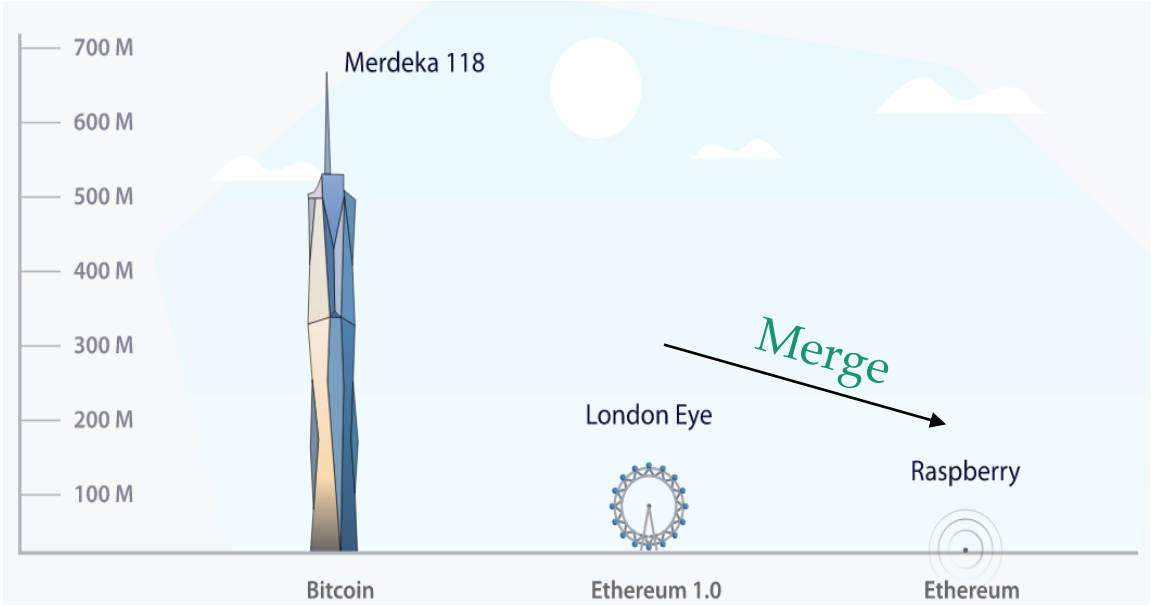
- **Motivations:** Larger scalability, faster transactions with less energy consumption than POW
- **When:** Completion on 15.09.2022
- **How:** Merge of the Mainnet (POW) and the Beacon Chain, where POS was already being tested before the Merge.

	Consensus M.	Redundancy
Hardware	POW → POS	L2 & Sharding
Software	POW → POS	L2 & Sharding

A comparison of the energy consumption differences between BTC, ETH 1.0 and ETH 2.0.



Source: https://ccaf.io/cbnsi/ethereum/ethereum_merge

The Merge led to a 99.9% decrease in energy consumption and carbon footprint.

The Merge and POS Ethereum

The effect of a consensus mechanism change

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Change from POW to POS = **change of security provision** from doing work, to providing security with financial stake.

→ The **work-related electricity consumption** and need for highly specialized hardware disappears.

Remaining electricity consumption =
Smart contract execution + simpler hardware electricity consumption + software electricity consumption

Result: Drastic decrease of environmental impact.

Source	Annualised electricity consumption (GWh)	Annualised carbon footprint (t CO_2 eq.)
Ethereum pre-Merge	21'410 – 22'900	10.3 – 11.0 **Mio.**
Ethereum post-Merge	1.96 – 2.6	750 – 870
PayPal	259.9	517'600

Per transaction comparison

Source	PayPal	Ethereum Post-Merge
Number of TX	22'300'000'000	1'751'094'429 (ETH) 583'698'142 (ERC20) (implied by gas)
Electricity consumption per transaction	11.7 Wh	1.3 Wh (ETH) 3.9 Wh (ERC20)
Carbon footprint per transaction	23.2 g CO_2 eq.	0.5 g CO_2 eq. (ETH) 1.5 g CO_2 eq. (ERC20)

Ethereum as a Proof-of-Stake blockchain is greener as PayPal, both in terms of carbon footprint and electricity consumption.

The Dencun Upgrade

Technical background

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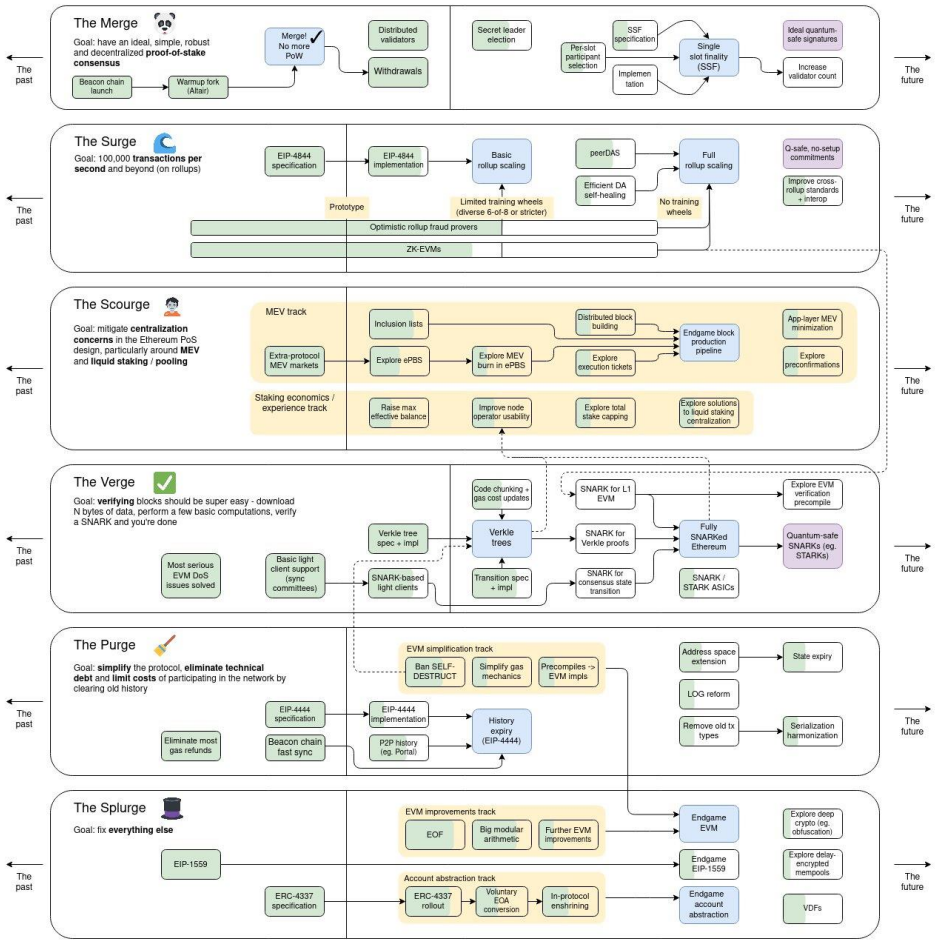
Dencun-Upgrade consists of 9 EIPs.

- **EIP 4844:** most important EIP, the Proto-danksharding, introduces blobs.
- **Blobs:** Temporary data storage (stored for 18 days on the Mainnet). Only these are being verified, not every transaction → reduces redundant calculations, increases throughput → decreases L2 gas fees

	Consensus M.	Redundancy
Hardware	POW → POS	L2 & Sharding
Software	POW → POS	L2 & Sharding

The Dencun-upgrade not only decreases L2 gas fees and increases scalability, but also reduces redundancy and makes Ethereum greener.

Ethereum's roadmap as seen by Vitalik Buterin.



Source: Tweet of Vitalik Buterin

The Dencun Upgrade

The effect of L2 and proto-danksharding

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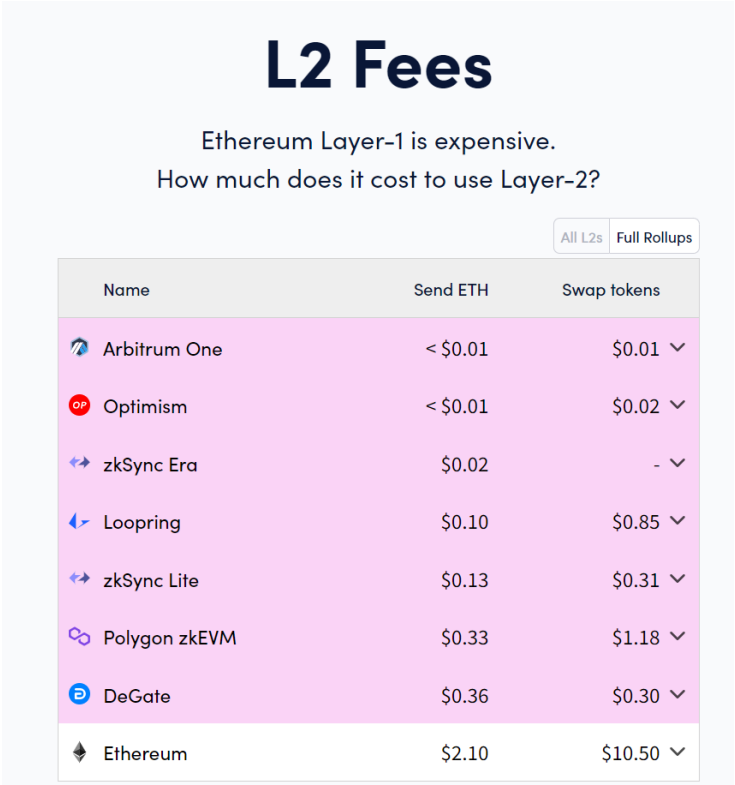
L2 and proto-danksharding reduces environmental impact

- **L2 and proto-danksharding** allows **more efficient allocation** of resources by reducing "unnecessary" redundancy
- **Effects on fees** are **mostly linear in energy and environmental aspects**, as L2 fees are mainly driven by L1 (optimistic roll-ups).

	Redundancy
L1 Ethereum	USD 2
L2 Optimistic Rollups	USD 0.02
Of which Dencun	80-90% reduction (last 30 days)

10-100x more efficient!

L2 Fees after the Dencun upgrade



Source: l2fees.info

L2 and proto-danksharding reduce environmental impact by 10-100x.

Discussion

Ethereum's strategy to increase throughput aligns with environmental goals

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Ethereum's strategy:

- Dencun is the start of *The Surge*-Era of Ethereum.
- **Goal of this era**: increasing scalability to 100'000 transactions per second.

Two main sources that determine the environmental impact:

- **Consensus mechanism**: The switch from energy (POW) to assets (POS) as security, reduces impact on the environment by 99.9% making Ethereum already greener than PayPal as a transaction layer.
- **Redundancy:** Temporary data storage (proto-danksharding) and aggregated verification (L2) reduce impact by approx. another 99%, making Ethereum significantly greener than other payment systems**.**

→ Ethereum's strategy to increase throughput aligns with environmental goals.

Future?

- More separation of tasks (e.g., proposer and builder?)
- Danksharding allows further reduction of redundancy, resulting in either lower validator specifications or higher throughput.
- Better understaning of the impact of various L2 types (i.e., zk-Rollups)?

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Thank you for your attention!

Beatrix Marosvölgyi
beatrix@cryptecon.org

Matthias Hafner
matthias@cryptecon.org

Center for Cryptoeconomics, c/o Swiss Economics, Ottikerstrasse 7, CH-8006 Zürich
www.cryptecon.org