Cointelegraph Research

UMINERS

Bitcoin Mining in 2025:

Post-Halving Economics, Hardware Evolution and Global Shifts

Cointelegraph Research Report

Content

Key Highlights

- Performance improvements in the manufacturing of SHA-256 ASICs will continue with the advent of 2 nm nodes in the latest semiconductor technology.
- The energy demand of current state-of-the-art SHA-256 ASICs ranges around 16–18.5 J/TH.
- Altcoin mining remains a niche sector with much lower protocol revenues. ASICs for alternative hashing algorithms exist, although they do not use top-of-the-line semiconductor technology.
- Bitcoin Network difficulty keeps hitting new all-time highs, most recently at 123 T. Together with the 2024 halving, this has compressed the margin of miners and recently made the hash price drop to $0.049 /TH/s
- The ever-increasing efficiency pressures on the industry have driven miners into the geographic periphery where energy is abundant and industrial and domestic demand is low.
- Corporate strategies in the mining space are becoming more sophisticated. Some public mining firms, such as Core Scientific and Bitfarms, are pursuing diversification into HPC applications, while others, including Marathon Digital, have adopted Bitcoin treasury strategies.
- A pivot to more open policies by the Chinese Communist Party could shift the center of global hashrate away from the US once more.

Introduction

> The 2024 Bitcoin halving reduced block rewards from 6.25 to 3.125 BTC. While anticipated, this event squeezed the profit margins of miners, compounded by rising energy prices.

To sustain profitability, some miners have focused on acquiring more efficient ASICs. Others increased their Bitcoin holdings in a bet on long-term price appreciation to offset shrinking block rewards and sustain operations.

Despite the mounting cost pressures, Bitcoin's network hashrate continues to climb (Figure 1).

Earlier in the year, hashrate peaked at 921 EH/s, marking a 77% increase from the 2024 low of 519 EH/s. This sustained growth, despite rising costs, shows that miners continue to scale. Larger firms are reinvesting in fleet upgrades to stay profitable as margins tighten.

FIGURE 1: BITCOIN NETWORK HASH RATE OVER THE LAST 12 MONTHS

Source: Hashrate index

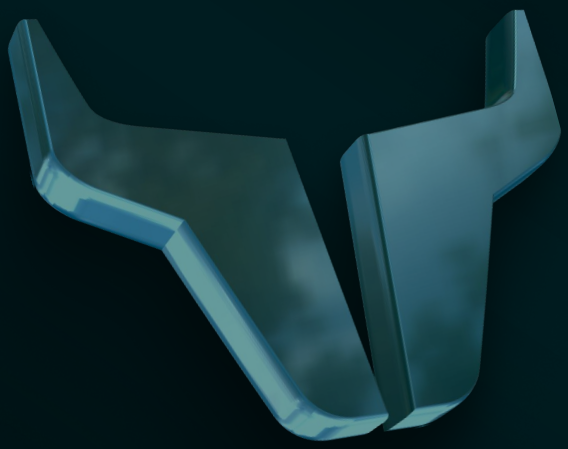
Against this backdrop, Uminers presents this report to analyze the evolving mining landscape. We survey the efficiency of different ASICs and their impact on the recent hashrate growth. The report also examines the profitability of mining operations since the halving as well as progress on sustainability initiatives, such as renewable energy adoption and the reuse of waste heat.

We will also discuss how miners are diversifying beyond their core business by repurposing infrastructure for high-performance computing (HPC), artificial intelligence workloads, and other compute-intensive services.

1. ASIC Equipment Survey

As block rewards shrink and competition intensifies, miners must extract more hashrate from each joule of electricity. Power efficiency is the primary determinant of hardware competitiveness.

The design of the latest models from leading ASIC manufacturers, such as Bitmain, MicroBT, and Canaan, reflects this.



Achieving efficiency gains in hardware begins at the silicon level. Leading firms such as MicroBT and Bitmain rely on high-end semiconductor manufacturers such as TSMC and Samsung for their ASIC supply chain. Samsung's 3-nm node, which was introduced in mid-2022 and based on gate-all-around (GAA) transistor architecture, has been implemented in rigs such as the WhatsMiner M56S++.

GAA provides better electrostatic control, lower power consumption and greater transistor density. Samsung reports power savings of up to 45% and a 23% performance boost over its 5-nm process. TSMC is progressing toward 2-nm nodes, expected to enter volume production in 2025, with projected improvements of 10–15% in speed and 25–30% in power efficiency relative to its 3-nm N3E process. While the assumptions of Dennard Scaling no longer fully apply, smaller nodes still reduce transistor switching energy and allow for greater logic density.

Among the most recently released ASICs, Bitmain's Antminer S21+, released in early October 2024, delivers 216 TH/s at 16.5 J/TH.

MicroBT's WhatsMiner M6XS+ series, announced in mid-2024, includes air-cooled and hydro-cooled models, with the M60S+ reaching 210 TH/s at 17 J/TH and the M63S+ pushing 450 TH/s at the same efficiency, albeit with hydro cooling. Canaan's latest lineup, including the Avalon A1566 and A15Pro, has also improved, though it still lags behind competitors in efficiency.

A comparison of some top-performing ASICs (Table 1) shows that newer machines cluster around the 16–18.5 J/TH efficiency range, which is a marked improvement from earlier models, which required 30+ J/TH.

These gains in efficiency allow miners to operate profitably under tighter margins.

However, as these newer ASICs become widely adopted, they collectively raise the network hashrate, which drives up mining difficulty.

This dynamic shortens the economic viability of older, less efficient hardware, making upgrades a continuous requirement rather than an occasional optimization. As noted by Uminers, the operational environment remains one of the most important efficiency factors.

To maintain high performance, mining devices require a stable cooling infrastructure and effective protection against dust exposure.

In optimal conditions, leading models often perform comparably. However, in harsher environments, MicroBT machines have shown greater resilience to dust and temperature fluctuations.

TABLE 1: COST-EFFICIENCY, ENERGY-EFFICIENCY AND PROFITABILITY COMPARISON ACROSS ASIC GENERATIONS

Model	Generation	Hashrate (TH/s)	Energy Efficiency (J/TH)	Profitability per Day ($) @ $95,000 per BTC	Chip Transistor Size	Release Date
Bitmain Antminer S9 13.5Th	First-Gen	13.5	98.15	0.36	16nm	May 2016
Canaan Avalon A1166 72Th	Mid-Gen	81	42.22	1.24	16nm	August 2020
MicroBT Whatsminer M31S+ 80Th	Mid-Gen	80	42	1.54	12nm	December 2020
Bitmain Antminer S19J Pro 100Th	Early-Modern	100	29.5	3.42	7nm	April 2021
Canaan Avalon A1566 185Th	Modern-Gen	185	18.49	8.28	5nm	October 2024
MicroBT WhatsMiner M60S+	Latest-Gen	212	19.98	8.87	5 nm	October 2023
Bitmain Antminer S21+ 216Th	Latest-Gen	216	16.5	10.08	5 nm	October 2024
MicroBT WhatsMiner M66S+	Latest-Gen	216	17.0	14.85	5 nm	July 2024
MicroBT WhatsMiner M63S+	Latest-Gen	424	17.0	21.00	5 nm	July 2024
Bitmain Antminer S21E XP Hyd 3U	Latest-Gen	860	13.0	27.22	5 nm	December 2024

Source: Kryptex, ASIC Miner Value, MiningNow, Hashrate Index

UMINERS QUOTE:

> “Fleet upgrades are an ongoing process. Miners continuously seek to increase hashrate, balancing modernization of both hardware and hosting infrastructure with their power contracts and available budget. While a full upgrade cycle typically occurs every four years, miners in regions with lower energy costs may extend hardware lifespans across two cycles, maintaining profitability despite declining revenue. Thus, upgrades are staged and continuous, governed by budget constraints and contract flexibility rather than fixed replacement targets.”

Beyond efficiency and cost, miners must also weigh logistical and operational risks when selecting hardware. Supply chain reliability, lead times, and long-term durability remain key considerations, particularly in a market where past disruptions have severely impacted availability and pricing.

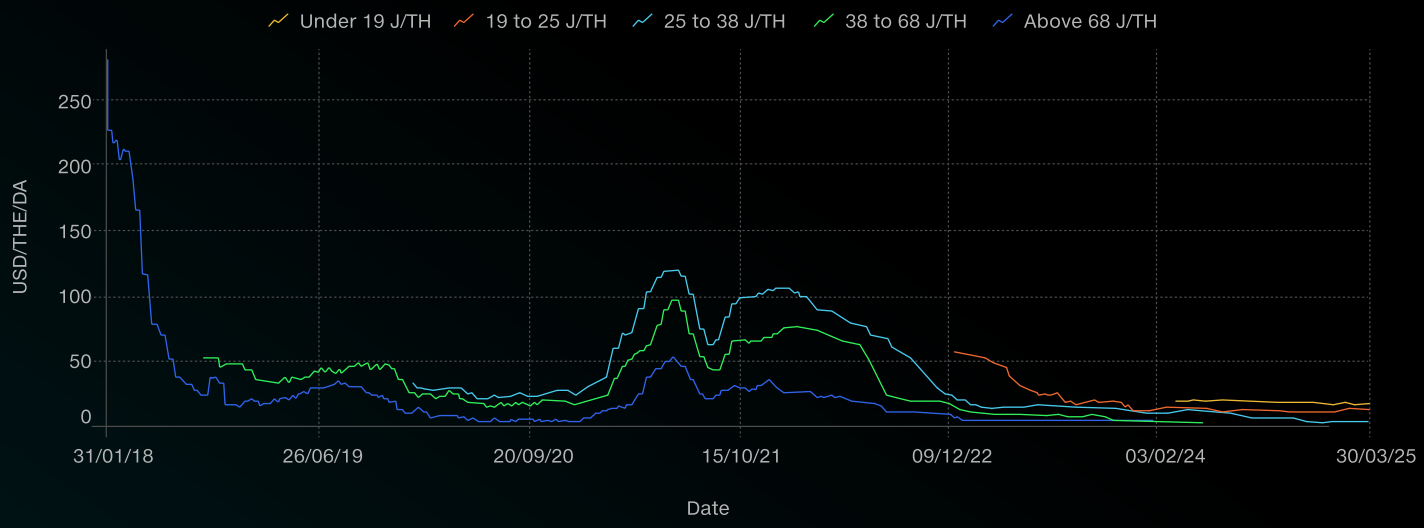
During the 2021 bull market, for instance, the Bitmain Antminer S19J Pro sold for over $7,900, with delivery delays that spanned several months. These delays were caused by logistical issues and the rising production costs for the new ASICs (Figure 2).

According to Uminers, supply chain disruptions have been a recurring issue between 2022 and 2024, and they are likely to persist into 2025–2026.

At the time of writing, these risks are less related to production capacity than to political and logistical volatility. US-based mining companies have already experienced shipping delays due to the recent trade tensions between the US and China.

In a fast-moving and competitive niche with long amortization periods, delayed deliveries can have a decidedly negative financial impact. This has enabled manufacturers who are capable of delivering consistent quality and support to catch up and solidify their positions as trusted suppliers.

FIGURE 2: ASIC PRICE INDEX



Source: HashrateIndex.com

ASIC hardware optimized for algorithms other than Bitcoin's SHA256 also exists. The mining of altcoins is typically associated with lower-cost manufacturing and faster innovation cycles but also carries higher risk due to thinner liquidity, weaker economic security, and volatile token incentives.

When comparing total network revenue, Bitcoin clearly outpaces its PoW peers by orders of magnitude. In 2024 alone, Bitcoin's network revenue, derived from block subsidies and transaction fees, was estimated at approximately $14.78 billion.

Litecoin (LTC), the next biggest mined token after Bitcoin with a market capitalization of approximately $7 billion, generated over $100 million in annual revenue, averaging around $350,000 per day. Monero (XMR) is another major PoW altcoin that does not use SHA-256. Its protocol revenues amount to roughly $40 million annually.

Monero's market capitalization stands at approximately $4.1 billion, and having entered its tail emission phase of 0.6 XMR per block, it now provides only modest rewards.

The specialized hardware for altcoin mining differs from Bitcoin's SHA-256 ASICs. Bitcoin ASICs are developed using cutting-edge semiconductor processes (e.g., 2 nm - 7 nm) produced by more advanced foundries such as TSMC and Samsung. Altcoin ASICs, on the other hand, employ lowerend manufacturing (e.g., 28 nm) by foundries such as GlobalFoundries and SMIC.

UMINERS QUOTE:

"Altcoin mining has always been part of the ecosystem, but today it's seen as a riskier, yet potentially more profitable activity. The Scrypt algorithm, which is used for mining Litecoin and Dogecoin (Table 2), remains one of the more attractive options, especially with reliable hardware like the Antminer L7, which continues to operate profitably into its second cycle."

This makes them easier and less costly to manufacture, which allows new entrants to adopt alternative production methods and adapt swiftly to evolving market demands.

TABLE 2: ALGORITHMS AND MINING DEVICES OF THE LARGEST POW ALTCOINS

Name	Hashing Algorithm	ASIC or GPU types
Dogecoin	Scrypt	Bitmain Antminer L9, VolcMiner D1, ElphaPex DG1+, Fluminer L1
Litecoin	Litecoin	Bitmain Antminer L9, Goldshell Mini-DOGE Pro, Fluminer L1
Bitcoin Cash	SHA-256	Bitmain Antminer S21, MicroBT Whatsminer M66S+, Canaan Avalon 1566
Monero	RandomX	Bitmain Antminer X5, GeForce 1000 series and newer, Radeon RX 400 series and newer
Ethereum Classic	Etchash	iPollo V2, Bombax EZ100, Bitmain Antminer E11, Jasminer X16-Q Pro, GeForce 1000 series and newer, Radeon RX 400 series and newer
Kaspa	kHeavyHash	Iceriver KS7, Goldshell KA BOX, Bitmain Antminer KS5, GeForce 1000 series and newer, Radeon RX 400 series and newer
Zcash	Equihash	Bitmain Antminer Z15, Innosilicon A9 ZMaster
Bitcoin SV	SHA-256	Bitmain Antminer S21, MicroBT Whatsminer M66S+, Canaan Avalon 1566
Conflux	Octopus	GeForce 1000 series and newer, Radeon RX 5000 series and newer
eCash	SHA-256	Bitmain Antminer S21, MicroBT Whatsminer M66S+, Canaan Avalon 1566

Source: whattomine.com

Given that demand for other PoW equipment is much smaller, there is also a risk of market saturation. An influx of manufacturers that produce specialized hardware for various altcoin algorithms could lead to an oversupply of devices, particularly if the targeted altcoin fails to achieve the needed adoption.

This oversaturation might trigger price wars among manufacturers, compressing profit margins and posing challenges for both new entrants and established players.

Uminers forecasts rising competition in the altcoin mining sector over the next 12 to 18 months as new players enter. Market consolidation is likely, with well capitalized firms absorbing share, particularly in SHA-256 altcoin mining.

Simultaneously, tokenized solutions and algorithm diversification will continue to drive demand for specialised mining devices, offering opportunities for manufacturers willing to invest in innovation in this area.

2. Mining Profitability Post-Halving

After the 2024 halving, miners were forced to rethink their cost structures. Even though Bitcoin's price has more than doubled since early 2024, the hashprice, a measure of daily revenue earned per terahash per second (TH/s) of mining power, has dropped significantly from $0.12 in April 2024 to approximately $0.049 as of April 2025 (Figure 3).

This decline indicates that rising competition is offsetting the recent price gains. Network difficulty surged to an all-time high of 123T in late April of 2025 and is thus up over 50% from the previous year.

As higher hashrates push up network difficulty, the profitability of individual miners decreases. Smaller operators and those with higher energy costs hence struggle to remain afloat (Figure 4). This has driven mining operations into the geographic periphery, where energy is abundant, but household and industrial demand is low.

The rest of this section will examine how regional electricity dynamics, government subsidies, and cost benchmarks are influencing mining strategies post-halving, particularly across the Middle East.

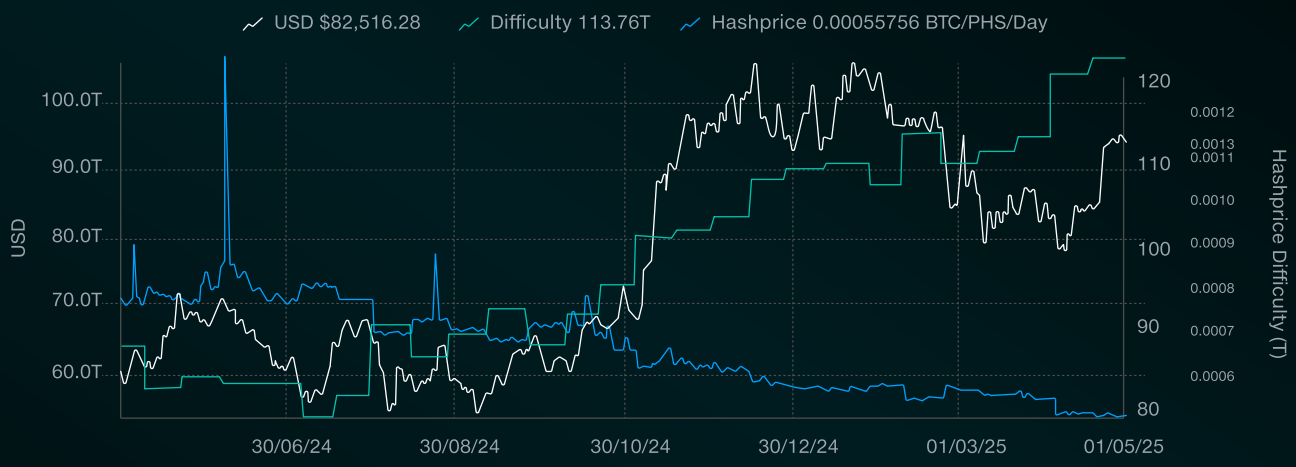
FIGURE 3: BITCOIN HASHPRICE IN TH/S

Source: HashRate Index

In the MENA region, Iran remains one of the most cost-effective jurisdictions. Licensed miners pay around $1,324.17 to mine a single BTC, which is among the lowest figures globally.

Oman and the UAE have also drawn attention from miners due to sovereign-led infrastructure buildouts and access to competitively priced power.

FIGURE 4: BITCOIN NETWORK DIFFICULTY



Source: HashRate Index

Holders of mining licenses can reportedly access subsidized rates well below commercial benchmarks, although final costs vary by site and scale.

The government has backed two licensed mining ventures, Exahertz and Green Data City, through preferential electricity tariffs and tax exemptions.

Assuming an average efficiency of 22 J/TH, their combined expansion plans could push Oman's share of global hashrate above 7% by mid-2025.

In the UAE, a similar strategy has taken hold. Industrial electricity rates range between $0.073 and $0.099 per kWh, which is prohibitively high for most miners.

However, semi-governmental projects like those led by Abu Dhabi's Zero Two reportedly secure rates in the $0.035–$0.045 range through long-term agreements. While this is not lower than subsidized residential rates, which sit at roughly $0.02/kWh for citizens and $0.012/kWh for agricultural operations, it does represent the lowest viable rate for scaling institutional mining under current market conditions.

These structured arrangements explain why firms like Marathon have based their regional operations in Abu Dhabi, where sovereign backing ensures regulatory clarity and infrastructure reliability.

In regions where electricity rates remain below or near the break-even threshold of approximately $0.06 per kWh, miners enjoy a distinct competitive advantage (Figure 5). For example, in the UAE, a Bitmain Antminer S21e XP Hyd 3U, which delivers 860 TH/s at 11,180 W, incurs a daily electricity expense of roughly $16 at $0.045 per kWh.

Under current revenue conditions, the model yields an estimated daily profit of $15, translating to monthly profits of around $450.

In comparison, miners in the United States with electricity rates around $0.09–$0.10 per kWh face daily expenses of $24.13 to $26.83, which reduces daily profits to a narrow range or even near break-even. At $0.12/kWh, the model operates at a loss, making mining unviable without supplemental income or preferential power contracts.

However, electricity costs are not the sole determinant of mining profitability. Full break-even analysis must also incorporate amortized hardware costs, infrastructure spending, and the timing of market entry.

Miners who purchased equipment during peak pricing cycles may struggle to recover their investment, even with electricity prices at $0.05–$0.06 per kWh.

Capital expenditures for data center buildouts, cooling systems, and long-term power contracts can significantly extend payback periods. While $0.06/kWh is commonly cited as a benchmark, it oversimplifies the economic calculus miners face.

Figure 5 visualizes the total and marginal cost to mine one Bitcoin over a time period, alongside corresponding electricity break-even thresholds. The left axis tracks cost in dollar terms, while the right shows the electricity price required to sustain profitability. The orange line marks Bitcoin's market price, while the green and blue lines show marginal and total production costs, respectively.

Their lighter counterparts reflect the electricity rates at which those break-even points occur. As costs converge with the BTC price, only miners operating below roughly $0.07–$0.08 per kWh maintain positive margins.

Alongside energy costs, selling, general, and administrative (SG&A) expenses weigh heavily on publicly traded miners. These costs encompass essential operational elements such as equipment maintenance, staffing, and regulatory compliance.

FIGURE 5: MONTHLY COST TO MINE BITCOIN

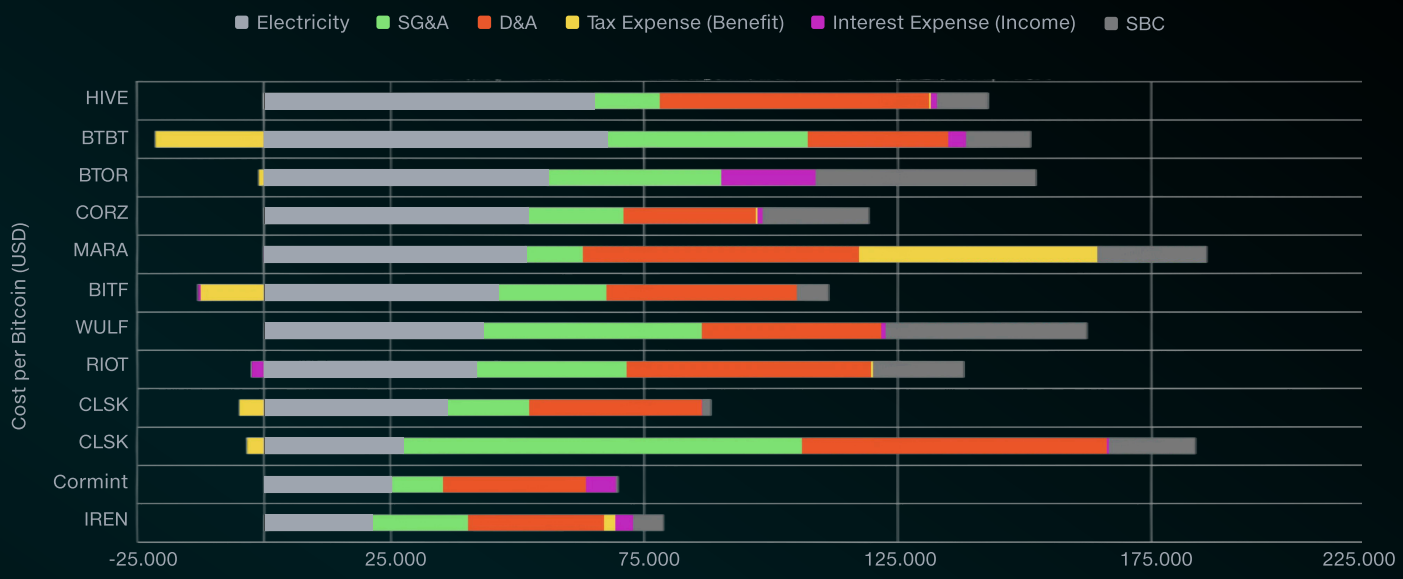
Source: Braiins

If costs had remained unchanged, the 2024 halving ought to have doubled the cash cost per Bitcoin; however, the Q3 2024 Bitcoin Mining Report by CoinShares indicates that the weighted average cash cost increased by only 13%, from $49,500 in Q2 to $55,950 in Q3.

This suggests that miners have implemented efficiency measures to partially offset the halving's impact.

However, the report also indicates that when non-cash expenses such as depreciation and stock-based compensation are included, the total production cost, in fact, exceeds $106,000 (Figure 6). Filings from publicly traded miners have reported that SG&A expenses can account for approximately 20–30% of their total operating costs.

FIGURE 6: TOTAL COST EXPENSES TO MINE ONE BITCOIN



Source: CoinShares (Data accurate as of April 2nd 2025)

3. Corporate Performance and Strategy

Public miners with higher break-even points, such as Argo Blockchain PLC and Riot Platforms, were particularly vulnerable during sustained market downturns in the recent past. Riot Platforms, for instance, reported an all-in cost exceeding $42,000 per BTC in Q4 2024, even after earning $13.9 million in power curtailment credits at its Rockdale facility. This is evident in their stock price, which ended the year at -84.89% and -34%, respectively.

By contrast, firms such as HUT 8 and Core Scientific that managed to lower SG&A expenses, either through automation or strategic downsizing, positioned themselves for the effect of the post-halving. The market rewarded this with 53.6% and 426% YoY gains in the stock price, respectively.

In response to increased operational pressures, miners have adopted a range of cost-management strategies that aim to safeguard profitability.

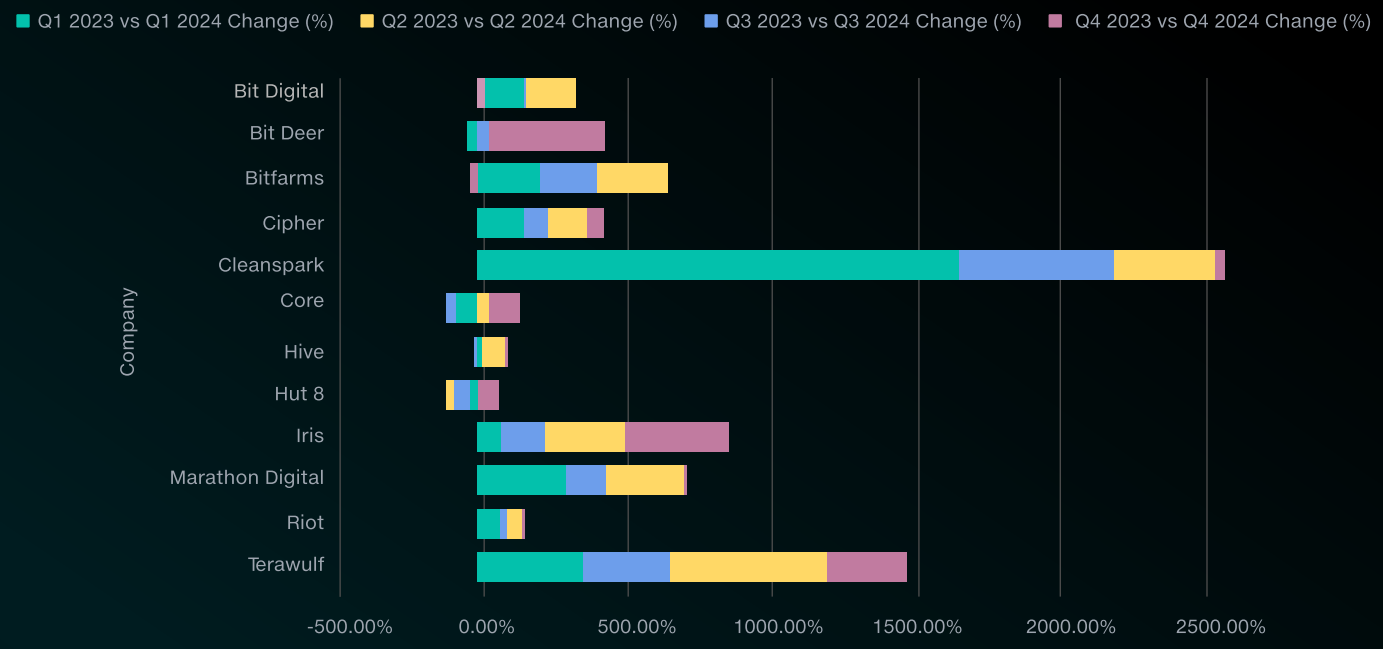
For instance, TeraWulf has secured a fixed-cost power contract at $0.02/kWh via its nuclear-powered Nautilus facility, achieving production costs as low as $18,700 per Bitcoin.

Similarly, Cormint has implemented advanced immersion cooling systems and in-house power management techniques to reduce production costs to approximately $14,900 per Bitcoin.

However, Cormint's Q3 results were marred by a $20 million hedging loss. While specific details of Cormint's hedging strategy are not publicly disclosed, they highlight the complexities of energy markets.

These factors not only strain operational budgets but also influence investor sentiment, as profitability and scalability become key indicators of long-term viability in an increasingly competitive mining ecosystem (Figure 7).

FIGURE 7: YEAR-OVER-YEAR CHANGE IN MARKET CAPITALIZATION FOR PUBLICLY TRADED MINERS IN THE US



Source: Cointelegraph Research, Q10 Reports, Yahoo Finance

Despite mounting challenges, public miners have also implemented strategic measures to enhance long-term balance sheet management and diversify revenue. Rather than realizing immediate profits, many miners are retaining their mined Bitcoin as balance sheet assets as future collateral for equipment financing or operational expansions.

Crypto-backed loans and flexible credit terms (now offered by Uminers) enable firms to fund infrastructure upgrades without liquidating their Bitcoin during unfavorable market conditions.

The impact of alternative, crypto-native revenue streams remains limited at the time of writing. While Ordinals and BRC-20 tokens briefly drove up network fees by increasing block space demand, their long-term effect on mining economics has been negligible.

Blockchains such as Stacks and Rootstock are additional revenue sources, but these, too, are negligible at the time of writing. Stacks distributes rewards to participating miners as part of its Proof of Transfer consensus mechanism. The related payouts amount to only 0.15% of Bitcoin's block subsidies in USD terms. Merge mining allows miners to validate sidechains, but its adoption remains even lower.

Uminers have also observed that beyond tokenized solutions, miners are increasingly leveraging their computational power for emerging business lines such as artificial intelligence processing and high-performance computing (HPC). This is a significant move to further diversify income streams.

For instance, in 2024, Bitfarms, a Canadian Bitcoin mining company, announced plans to repurpose some of its facilities to meet the growing demand for AI data centers. The company has engaged consultants to analyze its North American sites for potential AI and HPC applications, aiming to capitalize on the AI boom.

Similarly, in 2024, Core Scientific expanded its AI capabilities through a significant partnership with CoreWeave, an AI-focused cloud computing firm. This collaboration involves building 500 megawatts of infrastructure to support AI workloads, reflecting a strategic shift toward AI processing.

As of December 2024, the total market capitalization for crypto projects building AI initiatives reached approximately $33 billion. Over $382 million in venture capital invested in early-stage crypto AI startups that year. Due to these factors, Uminers anticipates that AI demand will continue to push miners to optimize infrastructure for compute-intensive workloads beyond Bitcoin.

Miners often turn to public capital markets to finance infrastructure upgrades and manage liquidity in a capital-intensive environment by raising funds through debt or equity.

For example, Marathon Digital raised $850 million through convertible debt to finance new facilities, and Riot Platforms has funded its Corsicana project via equity dilution and power curtailment credits.

These financing strategies have driven up financial leverage across the sector. Hut 8 Mining reported a 30% debt-to-equity ratio in 2024, up from 19% the previous year. Overall, while these instruments provide necessary capital, they also increase long-term financial risk for miners.

4. Development of Bitcoin Mining Globally

The global Bitcoin mining landscape continues to diversify, as it is shaped by energy economics, regulatory conditions, and access to infrastructure. While the United States and China remain dominant, emerging regions are starting to attract miners with cheaper power and untapped renewable energy potential. This section surveys how national policies and energy profiles are reshaping mining dynamics across key jurisdictions, beginning with the United States.

In the United States, transparency requirements and ESG standards are part of a broader trend toward sustainability. While federal policies remain almost nonexistent, they exist at the state level and differ significantly. Texas, for instance, actively encourages mining through supportive regulations and affordable energy.

The Public Utility Commission of Texas (PUCT) has implemented a rule that requires large-scale digital currency mining facilities, those with a total load exceeding 75 megawatts and at least 10% interruptible load, to register with the commission by Feb. 1, 2025. This measure aims to ensure future grid reliability while accommodating the growing energy demands of cryptocurrency miners.

New York has taken a more cautious approach due to environmental concerns. In 2022, the state enacted a two-year moratorium on new and renewed air permits for fossil-fueled power plants engaged in proof-of-work cryptocurrency mining. The legislation also mandated the New York State Department of Environmental Conservation (DEC) conduct a comprehensive study on the environmental impacts of such mining operations. As of October 2024, this study had not been completed.

Across the ocean, China's stance on cryptocurrency mining has evolved, albeit under stringent conditions, with an emphasis on sustainability.

The country remains a dominant force in ASIC production, as companies such as Bitmain and Canaan continue to drive global mining hardware supply.

While China's government officially banned crypto mining in 2021, data from CryptoQuant indicate that Chinese mining pools currently control around 53% of the global Bitcoin hashrate (Figure 8). However, this figure refers to pool operator jurisdiction and not the physical location of mining activity.

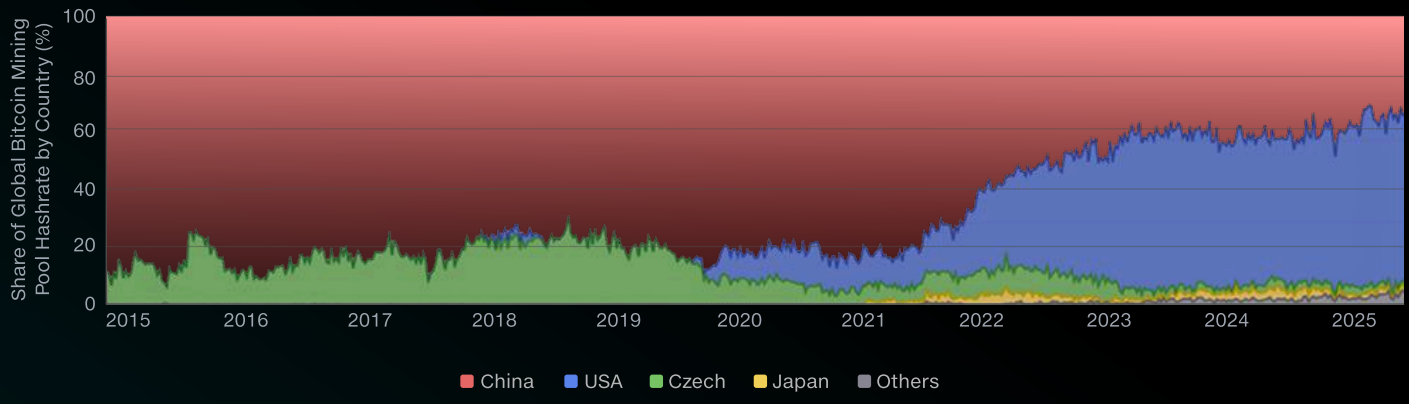
While China's government officially banned crypto mining in 2021, data from Crypto-Quant indicate that Chinese mining pools currently control around 53% of the global Bitcoin hashrate (Figure 8). However, this figure refers to pool operator jurisdiction and not the physical location of mining activity.

The share of global mining activity physically located in China stands at approximately 21%, placing it behind the United States, which accounts for around 38% of the total hashrate.

UMINERS QUOTE:

"If the government fully lifts the ban, China could quickly achieve global hashrate leader-ship, supported by domestic manufacturers and infrastructure providers. Some firms are reportedly mining on a limited basis using self-generated renewable energy in order to not harm general infrastructure. A full return would likely drive up network hashrate and compress global mining profitability."

FIGURE 8: BITCOIN MINING POOL HASHRATE DISTRIBUTION BY COUNTRY



Source: CryptoQuant

Future mining activity in China is expected to rely on renewable energy sources such as solar and gas generators, which could help stabilize regional grids by absorbing surplus energy from remote projects. While these regions continue to generate excess renewable energy, limited long-distance transmission infrastructure prevents full delivery to China's eastern industrial centers.

As a result, surplus energy is often curtailed or underutilized, thereby making local mining operations an efficient outlet for stranded power.

Before China's 2021 crackdown on cryptocurrency mining, provinces such as Sichuan and Yunnan were hubs for Bitcoin mining due to their abundant hydropower resources.

Miners capitalized on surplus hydro-power during the wet season to reduce operational costs and stabilize regional grids. As China's stance on Bitcoin mining evolves, there is potential for a resurgence in these areas, with operators once again tapping into surplus hydropower during the wet season.

Beyond China and the United States, Bitcoin miners worldwide are integrating renewable energy and efficiency solutions to cut costs and reduce environmental impact (Table 3). For instance, Ethiopia now contributes 2.5% of the global Bitcoin hashrate, with mining operations powered by hydro-power.

So far, only risk-affine investors are actively exploring the African Bitcoin mining market.

Uminers estimate that the continent could eventually contribute 7–10% of the global hashrate, though progress remains constrained by infrastructure challenges and political instability.

Europe has led the adoption of innovative solutions, such as waste heat recovery systems, which have emerged as another key component of sustainability.

These systems repurpose excess heat for industrial or residential use to improve resource utilization and foster partnerships with local communities.

In Norway, a hydro-powered Bitcoin mining farm repurposes waste heat to support greenhouse farming. Finland's Marathon Digital also supplies heating to over 80,000 residents by redirecting excess mining heat.

These examples highlight how miners are leveraging local energy resources and efficiency innovations to improve sustainability while maintaining profitability.

TABLE 3: GLOBAL BITCOIN MINING LANDSCAPE

Country	Electricity	Regulatory Status	Opportunities	Mining Adoption Rate	Challenges
United States	High energy costs	Favourable: Pro-innovation policies in states like Texas and Wyoming that support mining.	• Diverse energy sources, including hydro, nuclear, and flared gas utilization. • Strong financial infrastructure allowing public companies to raise capital. • Low energy costs in specific states i.e. Texas, Wyoming.	The largest Bitcoin mining hub globally.	• Regulatory uncertainty at the federal level regarding environmental concerns. • Increasing energy competition from other industries.
Canada	High energy costs	Favourable: Stable regulations.	• Government incentives for renewable energy mining operations. • Cold climate for cooling efficiency. • Low energy costs in certain provinces, i.e. Quebec and British Columbia.	Continued mining growth; remains a top-tier mining destination.	• Higher operational costs compared to some emerging mining developing countries. • Provincial restrictions on new mining projects due to energy allocation concerns.
Brazil	Moderately high electricity costs	Uncertain: Institutional players are kept on the sidelines	• Renewable energy source of Hydropower • Strong public interest in Bitcoin	Early stages of Bitcoin mining development.	• High import taxes and tariffs • Unstable energy pricing policies • lack of professional infrastructure.
Venezuela	Low energy prices	Uncertain: State intervention and frequent equipment seizures	• Some of the cheapest electricity rates globally • A historically strong mining community with technical expertise	Once a strong mining country. Has since deteriorated due to severe government crackdowns and grid instability	• Frequent power shortages make large-scale mining unreliable. • Economic sanctions and hyperinflation further destabilize the industry.
Nigeria	Low energy prices	Unstable: Government skepticism toward crypto	• Strong demand for crypto-related financial solutions • Potential for off-grid renewable mining operations.	One of the highest Bitcoin adoption rates in Africa.	• Mining infrastructure is almost nonexistent. • Frequent power outages and unreliable electricity grid. • High operating costs. • High energy costs relative to global mining hubs.
Indonesia	Moderately high energy costs	Uncertain: Government restrictions on cryptocurrency mining.	• Growing investor interest in Bitcoin could lead to mining infrastructure expansion. • Potential for geothermal and hydro-powered mining farms.	Limited mining taking place due to high energy costs and uncertain regulations	• High operational costs due to electricity pricing structures.
Argentina	Moderate energy costs	Uncertainty despite the pro-market government	• Growing foreign investment in industrial-scale mining farms. • Deregulation of energy markets allows direct energy contracts between miners and power producers.	Cheap electricity in Patagonia and Neuquén makes large-scale mining economically attractive.	• Regulatory uncertainties despite the pro-market government. • Infrastructure limitations in high-potential mining regions.
Kazakhstan	Moderate energy costs	Uncertain: Political instability due to macro geopolitical reasons	• Existing large-scale mining farms provide a solid foundation for further expansion. • Low energy costs due to abundant energy resources that remain available for miners who secure direct contracts.	Major mining hub after China's Bitcoin mining ban. Experiencing slow growth phase.	• Regulatory tightening and increased taxation have discouraged new entrants. • Government-imposed energy caps on mining operations. • Power shortages

Country	Electricity	Regulatory Status	Opportunities	Mining Adoption Rate	Challenges
Iran	Moderate energy costs	Uncertainty: Frequent policy reversals and mining restrictions	• Cheap energy rates for miners who secure direct contracts provide a competitive mining environment. • The government allows regulated mining licenses, albeit inconsistently.	Well-established Bitcoin mining industry	• Economic sanctions limit access to global markets and equipment. • Energy shortages and grid issues affect operational stability.
Malaysia	Moderately low energy costs	Moderately uncertain: Regulatory clarity is still lacking. Can go either direction.	• Government incentives for tech-driven industries could favor mining. • Expanding renewable energy capacity may provide long-term benefits.	Rapidly growing mining sector	• Environmental concerns over mining energy consumption. • Hardware importation costs remain relatively high.
Norway and Iceland	Moderate energy costs	Favourable: Pro-sustainable policies that can support Bitcoin mining.	• Near-zero carbon footprint operations make these countries attractive for ESG-focused investments. • Energy surplus and government incentives favor long-term mining stability. • Lower-end energy costs for miners who secure direct contracts or develop infrastructure due to abundant hydro & geothermal energy.	Growing mining sector; but concerns over scalability due to carrying capacity due to geography beyond a certain point.	• Limited scalability due to geographic and population constraints. • Higher capital expenditures compared to some low-cost energy nations.
Paraguay	High energy costs	Uncertain: Regulatory instability and evolving policy risks.	• Favorable climate and access to underutilized hydroelectric energy. • One of the lowest energy costs in the world for Bitcoin mining for miners who secure direct contracts.	Rapidly growing mining sector in 2022-2023. Currently is experiencing slower growth.	• Limited internal energy infrastructure for large-scale mining expansions.
Russia	Moderate energy costs	Uncertain regulatory environment regarding mining legalization.	• Cold climate and energy surpluses favor operational efficiency. • Cheap electricity rates for miners who secure direct contracts make it highly competitive for large-scale mining.	Steadily growing Bitcoin mining sector as massive untapped energy resources will be available in the future.	• Geopolitical instability and economic sanctions limit global investment.
Oman and Qatar	Moderately low energy costs	Favourable: Government-backed mining projects to diversify energy use cases.	• Access to extremely cheap natural gas energy.	Emerging industrial mining hubs poised for global competition in the mining sector	• Extreme heat conditions require additional cooling infrastructure. • Regulatory and geopolitical risks tied to global crypto policies.

Source: Cointelegraph Research, LinkedIn/ @Daniel Velloso

5. Sustainable Bitcoin Mining in the US

> The financial incentives for sustainable mining remain strong. Despite some asset managers, such as BlackRock, reducing their emphasis on ESG initiatives, miners investing in green energy solutions continue to attract institutional capital. Companies such as Crusoe Energy, Hut 8, and Riot Platforms exemplify this trend.

In 2022, Crusoe Energy secured a $350 million Series C round backed by G2 Venture Partners, Bain Capital, and Mubadala Investment Company (the UAE's sovereign wealth fund)—all firms with strong ESG mandates. Building on that momentum, Crusoe announced plans in 2024 to construct a 200-megawatt data center at the Lancium Clean Campus near Abilene, Texas. This facility is designed to support AI workloads and will utilize renewable energy sources. Crusoe has since expanded, with continued growth in 2023 and 2024 reinforcing investor confidence in sustainable mining solutions.

In 2024, Hut 8 Mining Corp secured a $150 million investment from Coatue Management, a major technology-focused investment firm. The funding supported the development of AI computing capacity through energy-efficient infrastructure.

Additionally, D.E. Shaw, a prominent investment firm overseeing $70 billion in assets, acquired a stake in Riot Platforms in early 2025. While the specific investment details remain undisclosed, reports indicate that D.E. Shaw may push for strategic changes at Riot, making it the second activist investor to do so. This move highlights not only the continued institutional confidence in the cryptocurrency mining sector but also the growing pressure for miners to refine their operational and financial strategies in an evolving market.

According to Uminers, MARA's acquisition of a Texas wind farm likely represents a strategic effort to lower electricity costs through energy diversification rather than a shift toward fully renewable mining. While renewables remain unreliable as a primary source, MARA can complement traditional energy mixes and support ESG positioning without compromising operational stability.

Conclusion

The 2024 halving has revealed that the economic logic of mining is evolving, as the market is maturing. For miners, profitability is no longer decided by energy efficiency alone. Instead, it depends on a miner's ability to operate across multiple layers of strategic complexity.

Today, Bitcoin mining as a business no longer resembles commodity extraction but infrastructure arbitrage. Factors that determine profitability are the agility to reprice risk, redeploy capital, and reconfigure workloads across jurisdictions. Across the report, one theme stands out. Miners who adopt newer ASICs and optimize financing and energy strategies are best positioned to remain viable in a market defined by compressed hashprices.

The ongoing expansion into the Middle East and Africa, makes one key driver of mining strategies clear: access to low-cost, policy-stable energy. In regions such as the UAE and Oman, state-backed infrastructure and long-term power agreements offer predictable margins, which attract institutional miners.

These jurisdictions are not just energy abundant, they are increasingly becoming the staging ground for scale-oriented operations that cannot thrive in high-cost, uncertain environments.

On capital financing, firms like Marathon and Riot turned to convertible debt and equity dilution to finance infrastructure buildouts and hedge volatility. Others have relied on power curtailment credits to lower effective costs. These strategies have become less about survival and more about preserving optionality in a capital-intensive, cyclically uncertain business.

Miners are also exploring new verticals. Several operators are repurposing excess capacity for high-performance computing and artificial intelligence workloads. These moves suggest that the definition of a miner is changing from just block production to compute allocation across a wider economic surface.

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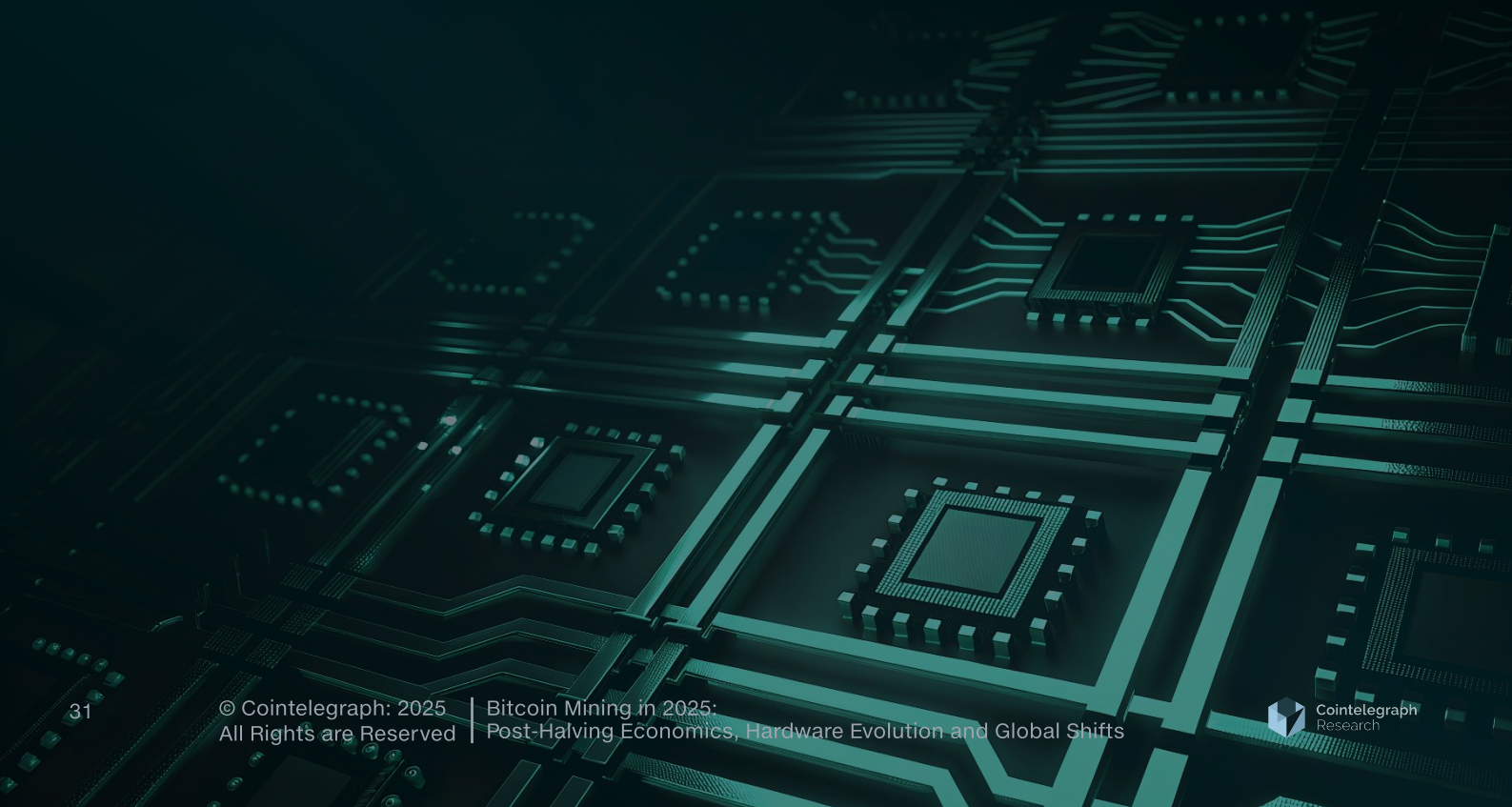

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