HASHRATE INDEX

Hashrate Index 2023 Year in Review: In the Shadow of the Halving

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About Hashrate Index

Hashrate Index is a Bitcoin mining data, analytics and research platform. Our platform offers novel data sets that enable miners, traders, content creators, and investors to gain key insights into the mining industry to generate alpha. Hashrate Index is a product of Luxor Technology Corporation, a Bitcoin mining software and services company.

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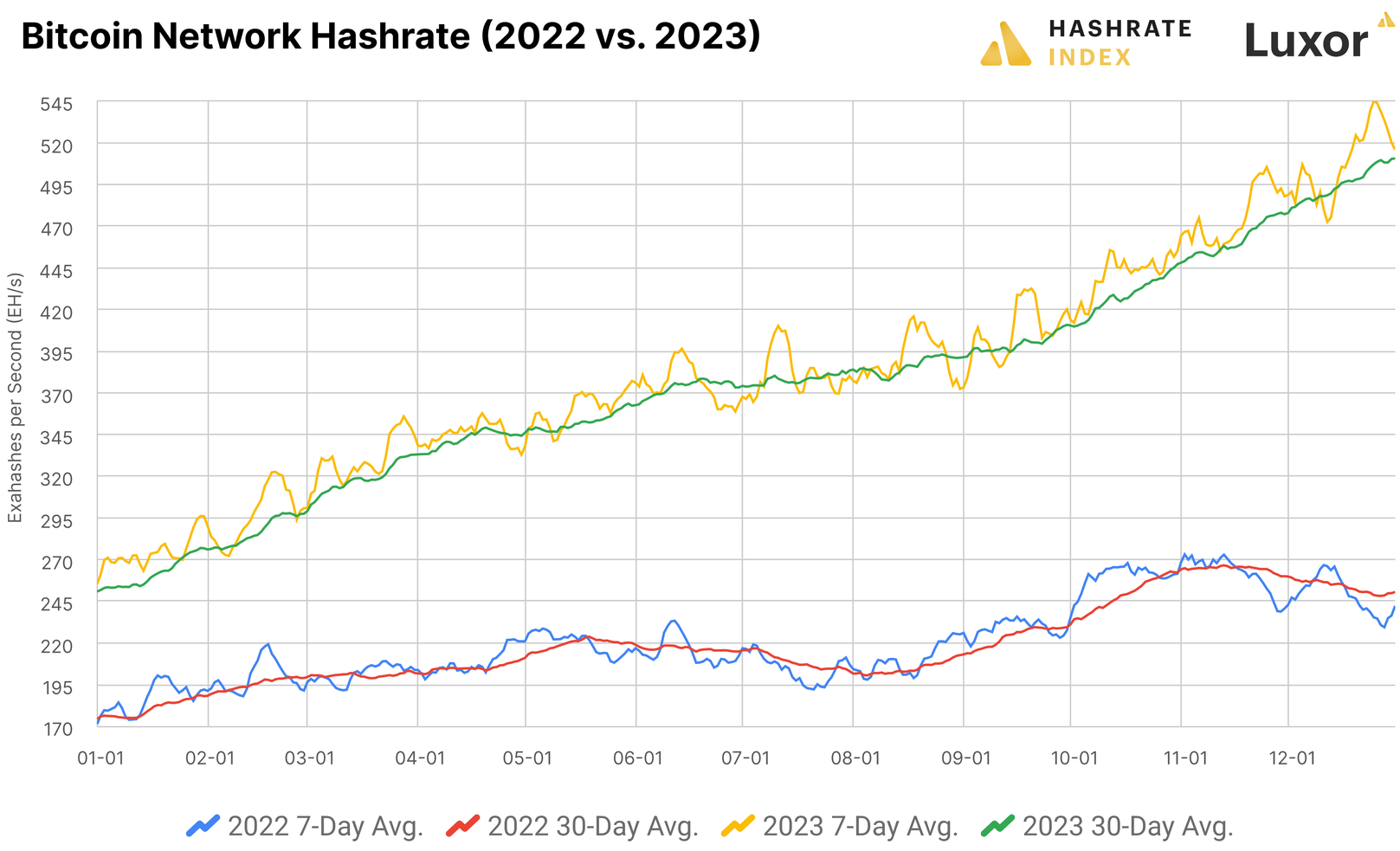
Introduction

2023 was a comeback year for the Bitcoin mining industry.

Bitcoin entered the year just under $17,000 in the aftermath of a market implosion precipitated by the folding of FTX's paper empire. Hashprice was treading in all-time low territory below $60/PH/day. The largest public Bitcoin miner, Core Scientific, was undergoing bankruptcy proceedings, while many other public miners like Iris, Greenidge, and Argo went through debt restructurings, and it looked like many other miners would soon be joining them. With hahsprice compressed and power rates inflating, many miners in the North American context were facing breakeven thresholds – if they weren't there already.

Then 2023 took miners on a surprising ride. Bitcoin's price recovered swiftly from its post-FTX-fallout lows and gained 149% over the course of 2023. Hashprice rose 71% over 2023, a much-welcomed reverse from 2022's 76% decline; this recovery was aided as much – if not more so – by a bull market in transaction fees from inscriptions and ordinals, a new standard for Bitcoin-based NFTs / digital collectibles that generated record levels of dollar-denominated transaction fee revenue for miners. 2023, by most markers, was a complete reversal of fortune from 2022's market ruin.

With this reversal, Bitcoin's hashrate experienced explosive growth in 2023. **Bitcoin's 7-day average hashrate swelled from 255 EH/s to 516 EH/s over 2023, a 102% increase that dwarfs 2021 and 2022's relatively modest increases of 18% and 41%. 2023's average for Bitcoin's 7-day average hashrate was 382 EH/s, a 73% increase from 2022's average of 220 EH/s. Bitcoin's hashrate hit all-time highs of 545 EH/s on the 7-day average and 510 EH/s on the 30-day average in 2023, as well.**

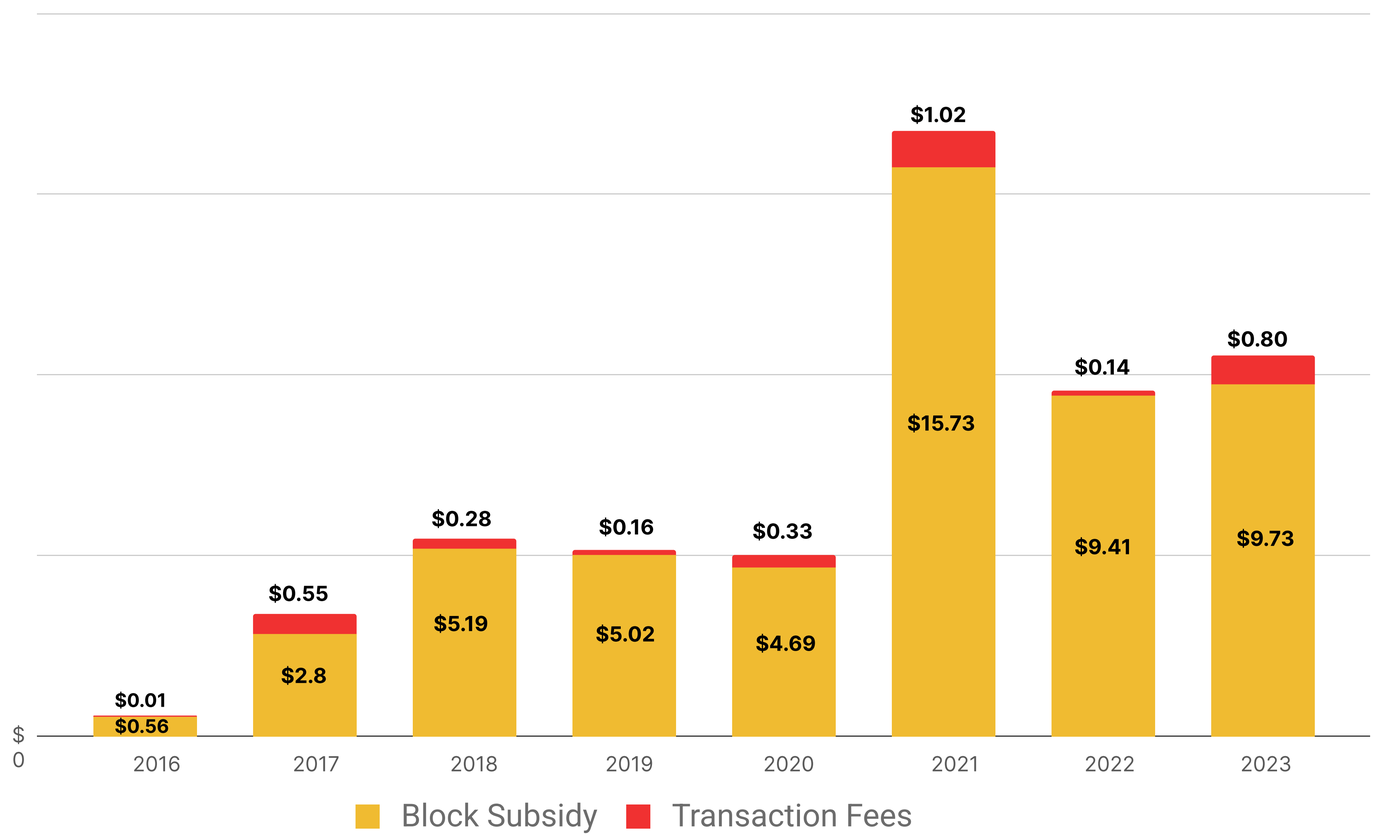


Source: Hashrate Index

Miners deploying next-generation ASICs like the S19 XP, S19j XP, S19k Pro, M50 series, and M60 series set the stage for 2023's hashrate growth. But the unexpected surge in hashprice from increases to both bitcoin's price and transaction fees furnished an encore; as hashprice rose and margins with it, older ASICs stayed profitable and miners with higher power prices could afford to stay online.

Indeed, 2023 witnessed $10.53 billion in total Bitcoin mining rewards, a 10.16% increase from 2022's $9.55 billion. Additionally, fees constituted 7.6% of these rewards, the largest share since 2017's level of 16.4%.

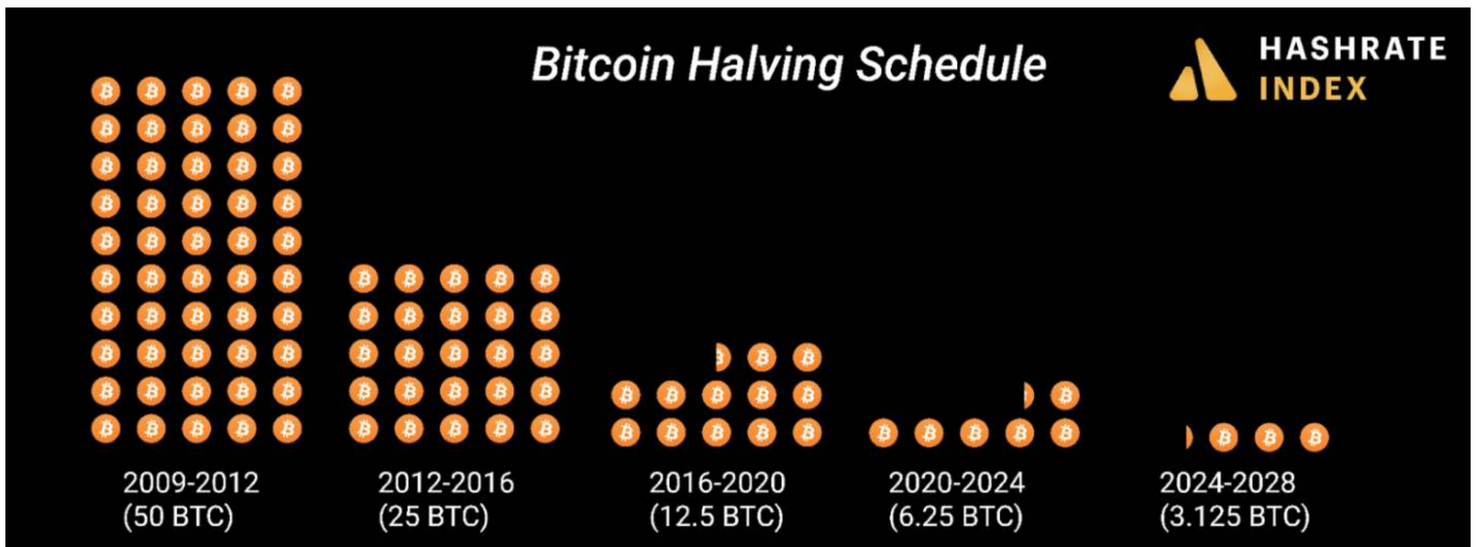
Bitcoin Mining Rewards from Block Subsidies and Transaction Fees (in Billions Rounded)



Source: Coin Metrics

In our 2022 year-end report, we said that the miner's mantra for 2023 would simply be to survive. 2023 delivered the opportunity to do just that, but despite the favorable market conditions compared to 2022, last year didn't exactly provide the means for them to thrive like we saw in 2021's bull market.

Last year provided a necessary second wind for an industry that was enervated by 2022's market downturn, but with 2024 upon us, miners have another Goliath to confront: the Fourth Halving. Bitcoin's Fourth Halving will reduce Bitcoin's block subsidy from 6.25 BTC to 3.125 BTC per block, thus reducing Bitcoin mining revenue by 50% in the blink of a block.



As it has in years past, 2024's Halving will no doubt indelibly alter the Bitcoin mining landscape. Unless Bitcoin's price experiences a bull run in 2024 that is comparable to 2021, then the event will compress margins below the all-time low levels experienced in Q4-2022.

2024 will be a make-or-break year for many miners. Those who spent 2023 preparing by upgrading their fleets with more efficient hardware, cutting excess costs, and optimizing their operations in every way will be the best prepared to weather the year.

Bitcoin Mining Companies

Mining Pools

ASIC Manufacturers

Colocation/Hosting Providers

Foundries

Miners

ASIC Brokerage

Container Providers

Research

Hashrate Derivatives

Custom Firmware

Mining Software

2

Hashprice Beats Expectations

2023 Average	2022 Average
$74.73/PH/day 0.00265 BTC/PH/day	**$123.87/PH/day** 0.00426 BTC/PH/day

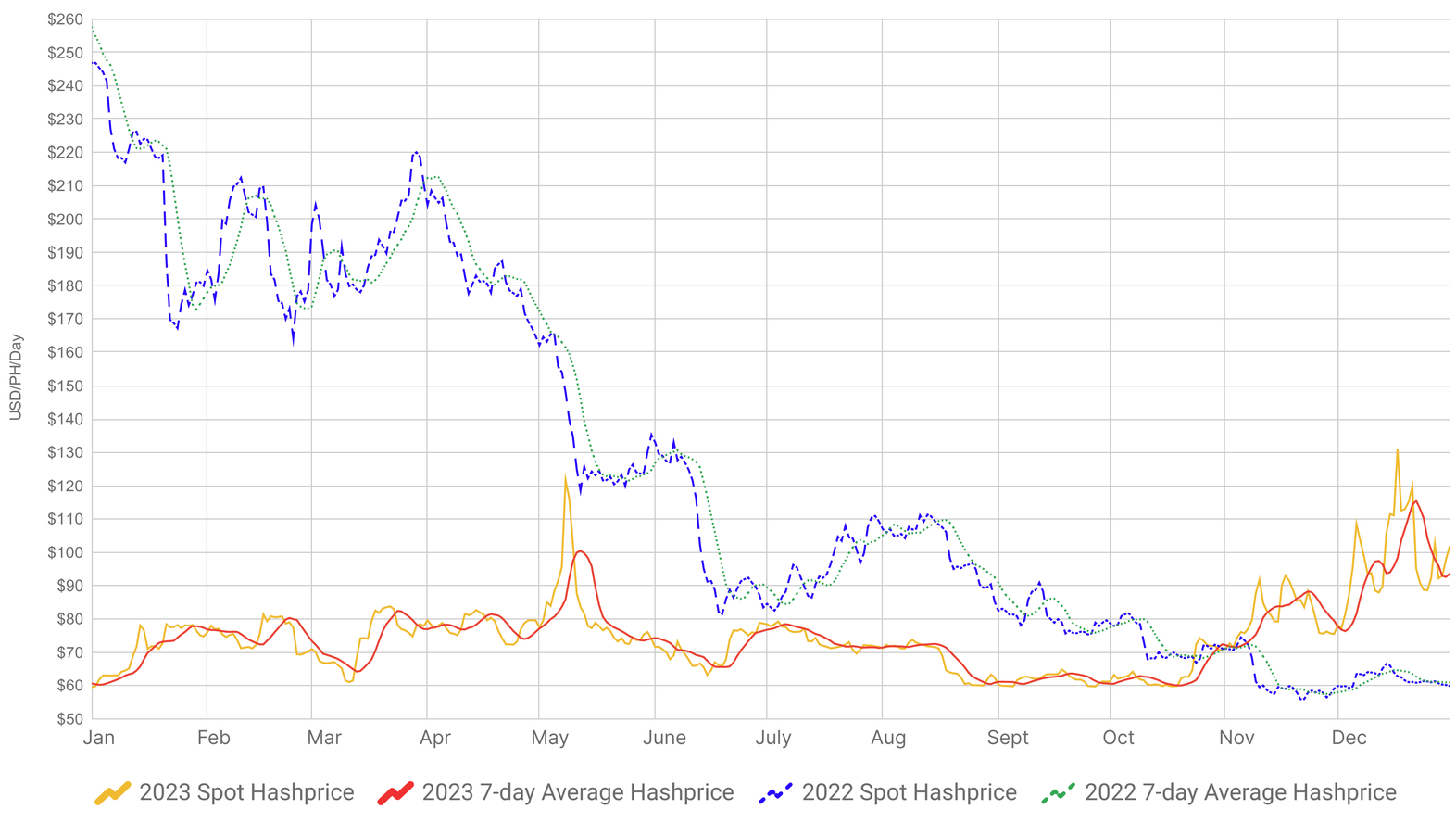
2023 Low	2022 Low
$59.42/PH/day 0.00199 BTC/PH/day	**$55.86/PH/day** 0.00345 BTC/PH/day

2023 High	2022 High
$130.97/PH/day 0.00433 BTC/PH/day	**$246.86/PH/day** 0.00528 BTC/PH/day

Hashprice entered 2023 near all-time lows, and most indicators pointed to it either trending lower or remaining flat for the year.

But along with bitcoin, USD hashprice exceeded market expectations in 2023, **rising an impressive 71% over the course of the year from $59.42/PH/day to $101.78/day; compare this to 2022, where hashprice declined 76% from $246.85/PH/day to $59.42/PH/day. Still, 2023's average hashprice was $74.73/PH/day versus $123.87/PH/day in 2022, a 40% decrease.**

USD Hashprice 2023 vs 2022



Source: Hashrate Index

The rise in hashprice comes from positive pressure both from bitcoin's change in price over 2023 (+149%) and recurrent swings in transaction fees from inscriptions and ordinals. **These forces were so positive, that over the course of 2023, hashprice saw its largest percentage increase since 2017.**

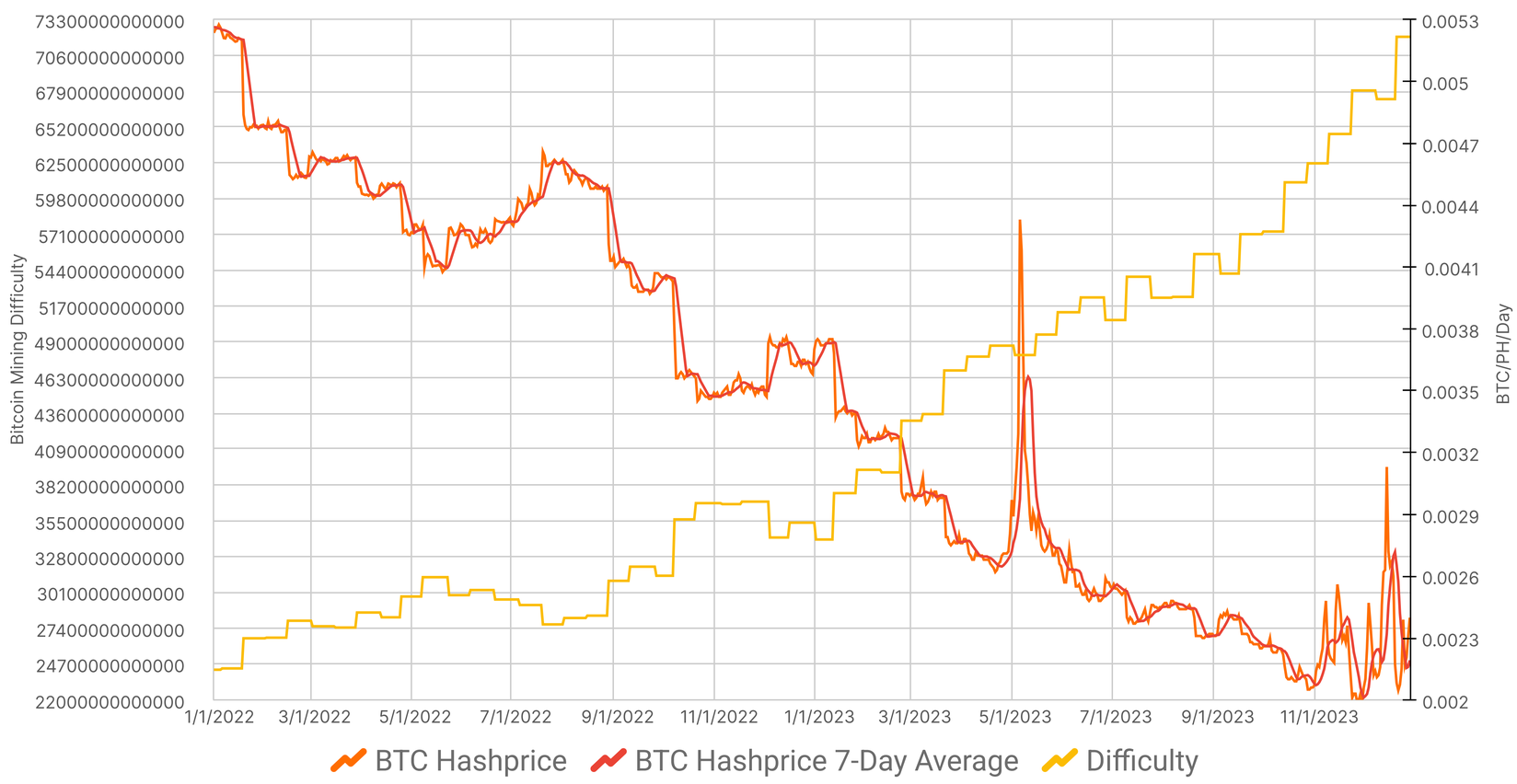
USD Hashprice Change	2017	2018	2019	2020	2021	2022	2023
Jan	-17.02%	-53.51%	-9.92%	10.09%	7.94%	-25.22%	27.77%
Feb	15.70%	-9.90%	6.55%	-9.01%	33.60%	7.51%	-6.60%
Mar	-20.11%	-46.04%	4.43%	-17.44%	20.86%	2.99%	12.20%
Apr	22.71%	15.80%	30.47%	27.71%	-2.61%	-20.76%	-2.71%
May	70.66%	-22.87%	46.75%	-41.84%	-36.53%	-17.99%	-7.61%
Jun	-22.89%	-28.01%	12.30%	-9.96%	3.31%	-36.42%	9.56%
Jul	-12.03%	1.94%	-20.05%	30.46%	53.33%	26.57%	-9.20%
Aug	85.32%	-17.04%	-20.54%	-5.29%	-4.65%	-22.96%	-15.39%
Sep	-35.58%	-13.13%	-25.85%	-18.60%	-10.80%	-4.65%	1.73%
Oct	24.56%	-4.60%	1.61%	45.37%	16.56%	-9.57%	15.20%
Nov	63.25%	-28.86%	-15.96%	26.36%	-8.57%	-15.77%	5.70%
Dec	2.78%	5.39%	-3.33%	49.03%	-25.04%	-0.69%	25.31%
Annualized	171.88%	-92.36%	-16.19%	52.28%	15.94%	-75.94%	71.28%

Source: Hashrate Index

Further, hashprice increased despite significant pressure from Bitcoin mining difficulty. **Bitcoin's difficulty doubled in 2023, rising 103.6% from 35.36 trillion to 72.06 trillion**. Out of the 27 difficulty adjustments that occurred in 2023, only 7 of these were negative adjustments; both the largest negative adjustment and largest positive adjustment came in the month of January, a respective -3.59% change on January 2 and a +10.26% change on January 15.

As a result of the changes to Bitcoin's mining difficulty, BTC-denominated hashprice decreased 33% in 2023 from 0.00359 BTC/PH/day to 0.00240 BTC/PH/day, basically on par with 2022's 31% decrease from 0.00524 BTC/PH/day to 0.00361 BTC/PH/day. 2023's average BTC hashprice was 0.00265 BTC/PH/day, a 38% decrease from 2022's average of 0.00426 BTC/PH/day; this average would have been markedly lower if not from 2023's high transaction fee volumes.

BTC Hashprice (Spot and 7-Day Avg) vs. Bitcoin Mining Difficulty



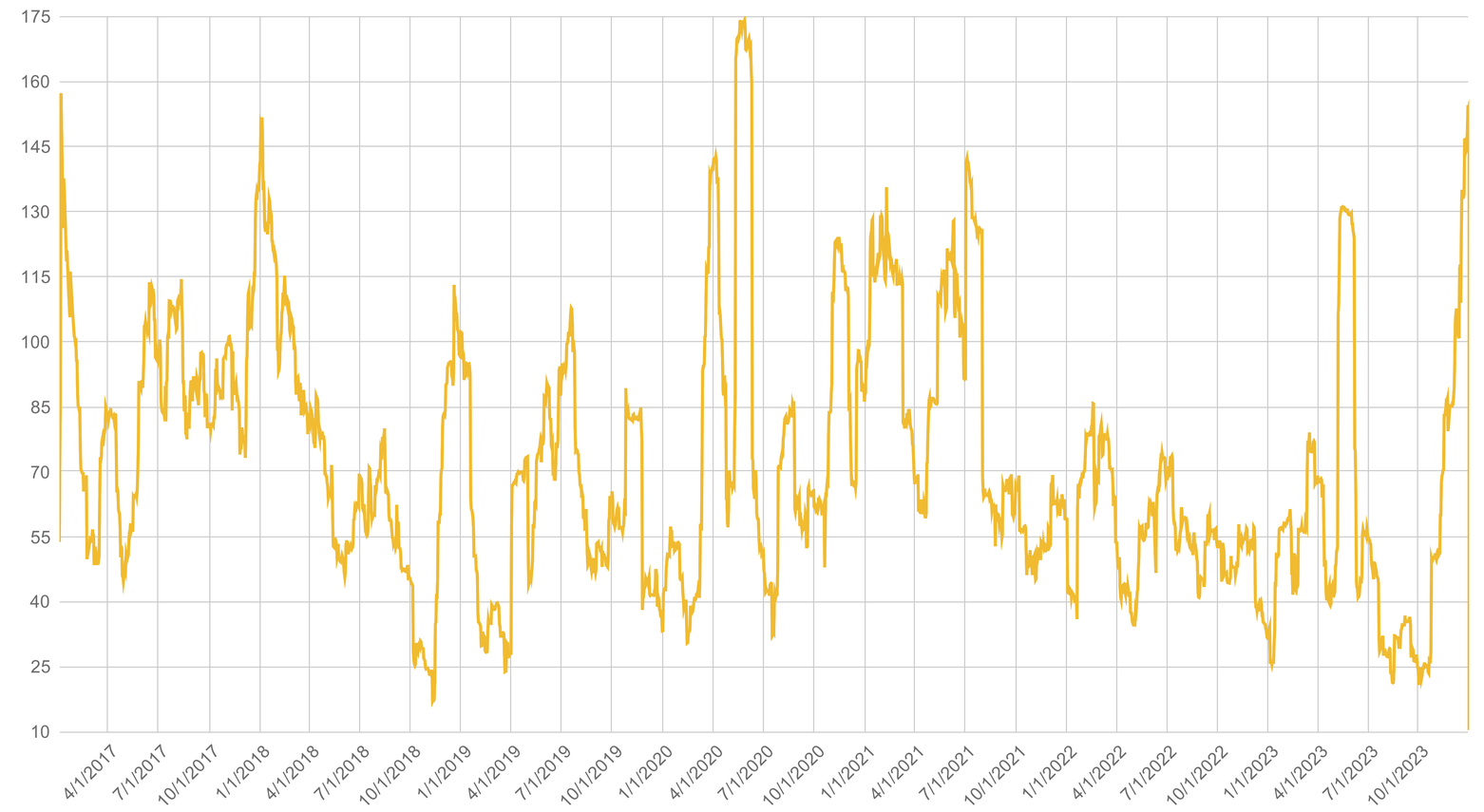
Source: Hashrate Index

Hashprice Volatility Hits Multi-Year High

Largely as a result of inscriptions-induced swings to transaction fees, hashprice had a significantly more volatile year in 2023 than 2022.

2022's hahsprice volatility was marked by bitcoin's eroding price. When bitcoin found a floor as 2022 turned to 2023, volatility dropped to its lowest level since July 2020, and it dropped again to a multi-year low on the first day of October, reaching its lowest point since November 2018. By the end of the year, the transaction fee bull run tossed hashprice volatility to its highest level since May 2020, a time when hashprice was reacting to Bitcoin's third halving. (When measuring volatility, the higher the number, the more volatile an asset over the 30-day rolling period and vice versa for a low score).

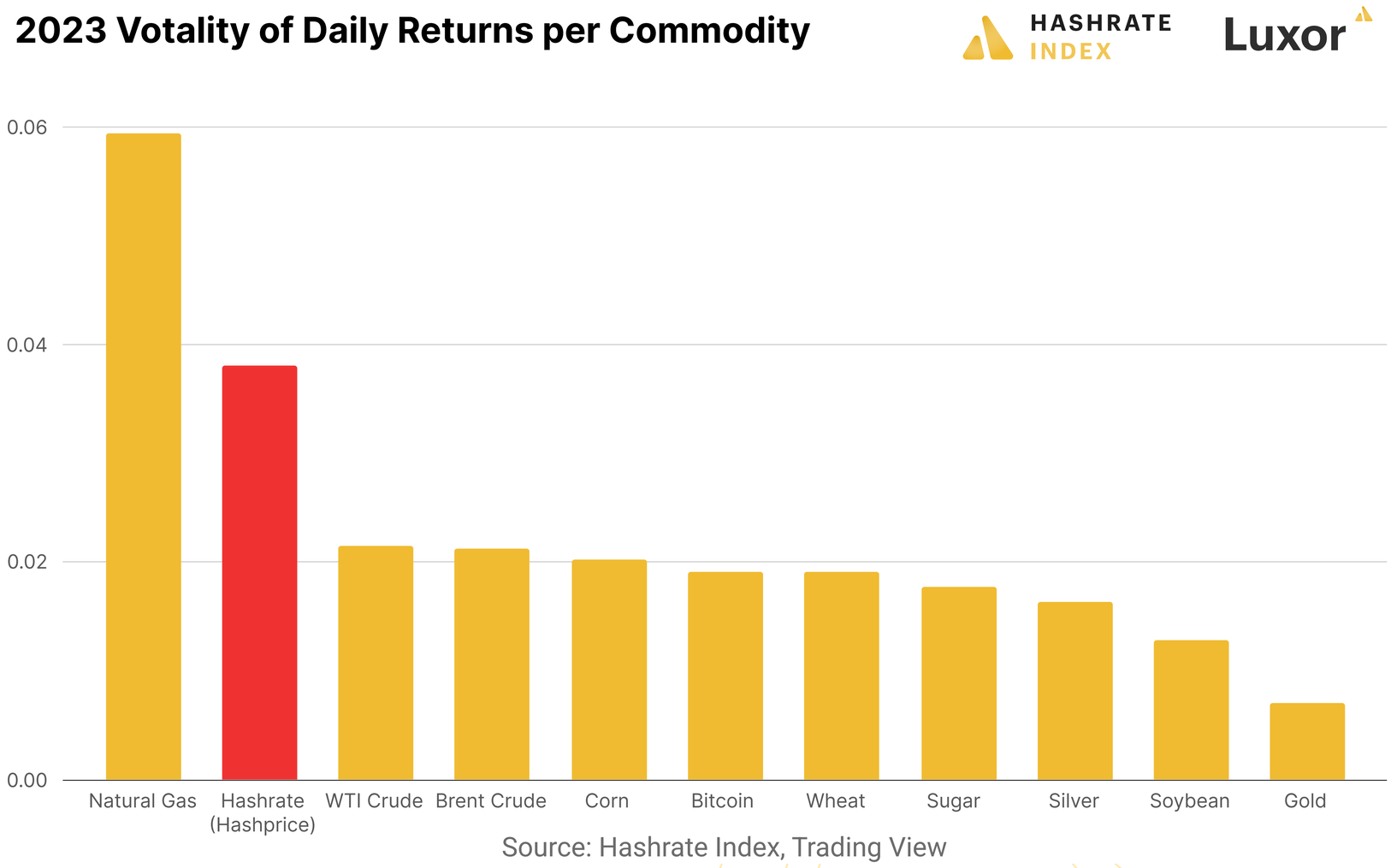
USD Hashprice 30-Day Rolling Volatility



Source: Hashrate Index

Taking a look at hashrate in the broader market of commodities, hashrate volatility (as measured by hashprice) ranked second highest amongst the most traded commodities in the world. This volatility adds to the complexity miners face when planning and operating their businesses. As we will cover in the next section, ordinals and inscriptions complicate this volatility, as they are precipitating positive changes to hashprice irrespective of changes to Bitcoin mining difficulty.

2023 Votality of Daily Returns per Commodity



Source: Hashrate Index, Trading View

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Hashrate Derivative Markets in 2023

In 2023, hashrate derivatives saw rapid maturation.

In response to the challenging economics of Crypto-Winter, Federal Reserve rate tightening, and relentless hashrate growth, miners began to consider revenue hedging strategies. However, in 2022, miners only had Bitcoin futures and a small patchwork of physically-settled hashrate forward options available. These limited hashrate hedging options left many miners exposed to significant hashprice risk and made it difficult for them to access capital and build defensible businesses in a highly cyclical industry.
Below is an overview of Bitcoin mining derivative marketplaces in 2023.

Bitcoin Mining Derivative Products	Description	Providers
Hashrate Forward Marketplace	• **Over-the-Counter** • **Standardized contracts and product options**	• **Luxor**
Bitcoin Derivatives	• Exchange traded or over-the-counter • Only Bitcoin price exposure • No direct difficulty or transaction fee exposure • Helpful for currency exchange or treasury risk	• CME • Deribit • EDG • FalconX • Galaxy • GSR • NYDIG • Orbit Markets
Cloud Mining	• Over-the-counter • Market operator often serves as the seller and/or determines prices • Smaller size buying opportunities • Overseas retail demand • Headquartered overseas	• Binance • BitDeer • BitFuFu
Deliverable Hashrate Marketplaces	• Over-the-counter • Facilitates buyer-seller matching • Limited product options • Lack settlement standardization	• BitOoda • Block Green • Navier Reactor • Rigly
DeFi Hashrate Marketplaces	• Decentralized finance marketplaces • Experimental and unregulated	• Alkimiya • Lumerin

Bitcoin futures and forwards are helpful tools for miner's looking to mitigate currency exchange and/or treasury risk. However, on the revenue-side they do not protect against fluctuations in network difficulty (i.e., hashrate) or transaction fees. Historically, these have been small components of hashprice, but as the block subsidy is reduced they become a more important part of a Bitcoin miner's revenue.

Miners have limited opportunities to sell forward on cloud mining platforms, where the market operator often serves as the seller and/or determines prices. Buyers typically make full upfront payments, while external sellers encounter strict payout and margin requirements. Cloud mining platforms mainly attract smaller-sized buying opportunities, with demand primarily originating from overseas retail buyers. Additionally, many of these companies are headquartered outside the United States.

Deliverable hashrate marketplaces, facilitating buyer-seller matches, suffer from a lack of product options and standardized contracts. These markets commonly provide restricted delivery choices (mostly physical, with no cash settlement), limited currency denominations or compulsory use of the market's "token", and constraints on durations and payment timing. Crucially, they often lack an index for accurate settlement of hashrate contracts to their true value over time. Compensation for missed deliveries involves delivering hashrate at a different time, introducing uncertainty into settlement amounts as the value may have changed.

Decentralized finance (DeFi) remains inaccessible to numerous commercial mining firms and institutional investors due to its experimental and unregulated nature. There are also concerns about managing counterparty risk and the lack of KYC/AML that make these markets a non-starter for institutional miners.

Luxor Hashrate Forwards in 2023

Luxor Derivatives spent 2023 changing the hashrate forward landscape.

After beta-launching 30-day, non-deliverable hashrate forward (NDF) markets in October 2022 that were USD-denominated, Luxor started 2023 by adding BTC-denominated NDFs, while extending durations up to 3-month / 90-days. This gave miners the ability to hedge Bitcoin price separately from difficulty and transaction fees (BTC-denominated hashrate forwards) or all in one product (USD-denominated hashrate forwards) for a longer, more useful period of time.

In late January, Luxor launched the Luxor Position Manager – a new platform to manage hashrate trading positions. The application is loaded with risk management functionality, designed for customers to manage existing positions, see daily mark-to-market, monitor profit and loss, and view the overall performance of their hashrate forward positions. In November, Luxor added an order book to the platform where buyers and sellers meet to transparently exchange hashrate at specified prices. This new front end tool allows market participants to see current bids and offers, as well as the forward curve of the market.

In July, Luxor extended contract durations up to 6-month / 185-days, and introduced monthly pricing, daily settlement, and dynamic margin. While longer durations increased the usefulness of the hedging instrument and opened up longer term investment opportunities, monthly pricing, daily settlement, and dynamic margin, made Luxor's hashrate forward much more capital efficient.

And finally in November, Luxor launched deliverable hashrate forwards with upfront payment options for miners. This addition to Luxor's hashrate derivatives suite empowers Bitcoin miners to secure future revenue by locking in upfront payment directly in their Luxor Mining Pool accounts, providing Luxor clients with yet another way to secure income from their hashrate. This changes the game for how miners can monetize their hashrate. Luxor miners can now choose between spot payout methods for their hashrate (i.e., FPPS payout) and forward payout options with upfront or fixed future payment.

Date	Luxor Hashrate Derivatives Product Releases
October 6, 2022	• USD-denominated non-deliverable forward contracts • Up to 30-day durations
January 1, 2023	• BTC-denominated non-deliverable forwards contracts • Up to 3-month or 90-day durations
January 29, 2023	• Luxor Position Manager
July 10, 2023	• Up to 6-month or 185-day durations • Monthly pricing • Daily settlement • Dynamic margining
November 7, 2023	• Luxor Hashrate Forward Order Book
November 13, 2023	• BTC-denominated deliverable forward contracts • Upfront payment options

All this work has helped Luxor to develop the most transparent, secure, standardized, and liquid hashrate forward marketplace. Today, the buyer and seller of a Luxor Hashrate Forward contract simply agree to the following variables:

1. Unit Hashprice (e.g., $80/PH/s/Day or 0.00220 BTC per PH/s/Day)
   - USD or BTC-denominated contracts
   - Upfront or fixed payment

2. Daily Hashrate (e.g., 100 PH/s/Day)
   - Deliverable or non-deliverable

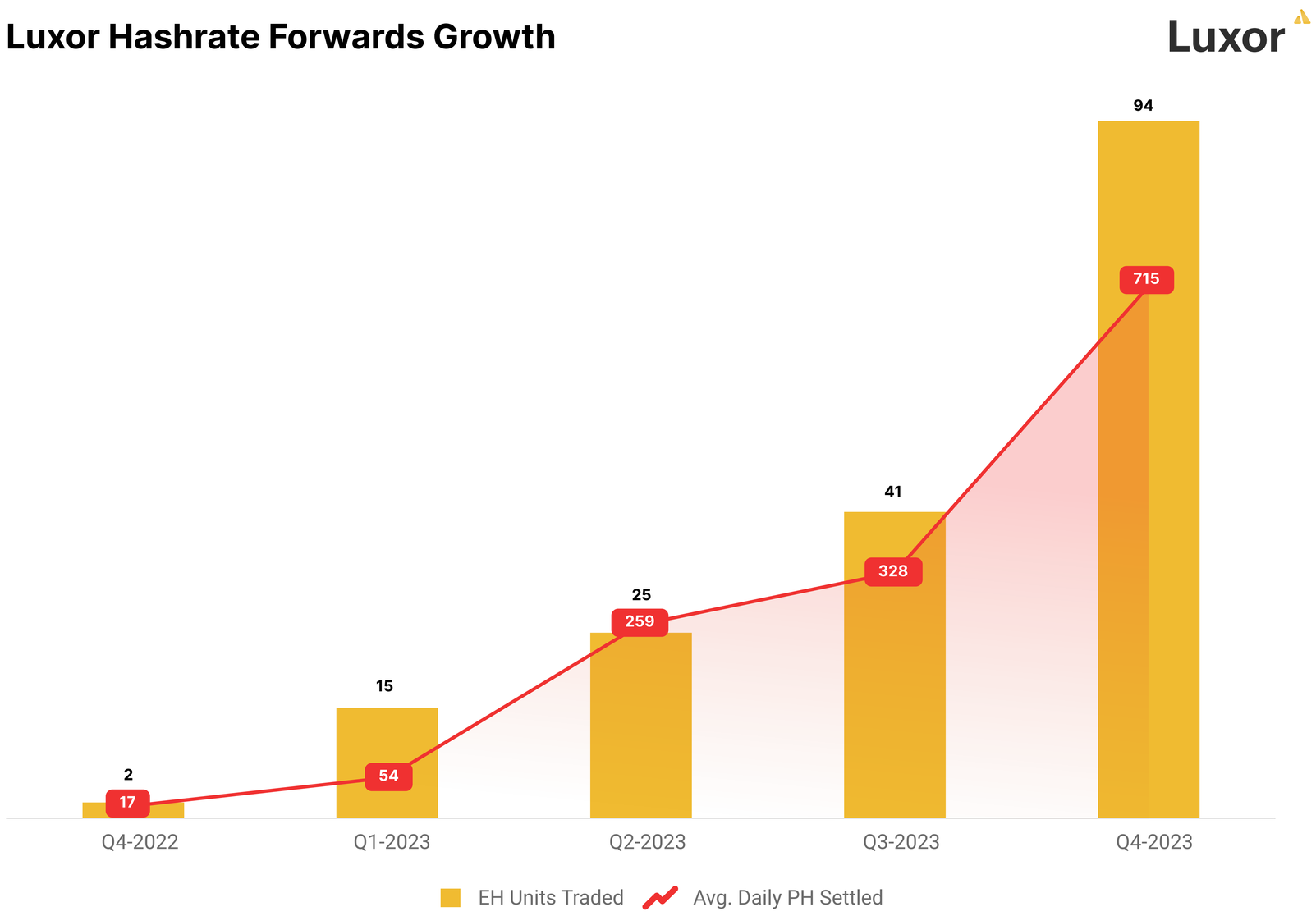
3. Dates (e.g., December 2023)

- Monthlies available out to a maximum of six months.
- Custom contract durations are also available
-

Luxor facilitates the contract by providing the following services:

- Matching counterparties
- Promoting price discovery
- Managing counterparty risk
- Luxor Position Manager for daily profit and loss calculation
- Acting as the settlement agent as the contract is settled to Luxor's Bitcoin Hashprice Index.

In just under a year, Luxor Hashrate Forwards have seen tremendous growth in the number of market participants and total volume traded.



Source: Luxor Derivatives Desk

Hashrate Derivatives Markets in the Year Ahead

We expect that large Bitcoin mining companies will initiate hedging strategies to reduce capital costs and increase valuations and net income in the year to come.

In 2024, we anticipate mainstream adoption of hashrate hedging, with nearly every major Bitcoin mining company implementing a hedging strategy. The rationale is straightforward: the halving and increasing difficulty will significantly diminish industry margins, compelling miners to use hashrate derivatives for margin protection. Historically, large public companies have refrained from hedging, but Luxor has observed the initiation of hedging strategies among smaller public and large private miners, along with growing interest from larger public companies.

Annual Filing Disclosures on Price or Hashrate Hedging Activity

Explicitly States That They Do Not Hedge	
Company	**Statement**
Cleanspark	Because we do not currently hedge our investment in bitcoin and do not intend to for the foreseeable future, we are directly exposed to bitcoin's price volatility and surrounding risk.
Cipher	Because we do not currently hedge our investment in bitcoin and do not intend to for the foreseeable future, we are directly exposed to bitcoin's price volatility and surrounding risks.
Hive	The Company has not hedged the conversion of any of its coin sales or future mining of digital currencies.
Hut8	The Company has not hedged the conversion of any of its sales of Bitcoin.
Bitdeer	We currently do not use any derivative contracts to hedge our exposure to cryptocurrency risk...
TeraWulf*	We do not hedge our bitcoin.
Bitfarms**	Because the Company does not currently hedge its investment in BTC, the Company is directly exposed to BTC's price volatility and surrounding risks.
Stronghold***	We do not currently hedge our investment in Bitcoin and do not intend to for the foreseeable future.

Explicitly States That They Hedge	
Company	**Statement**
Argo	In 2022, the Group used derivatives contracts in connection with some of its lending activities and its treasury management. The Group participates in both Future and Forward contracts as well as option contracts.

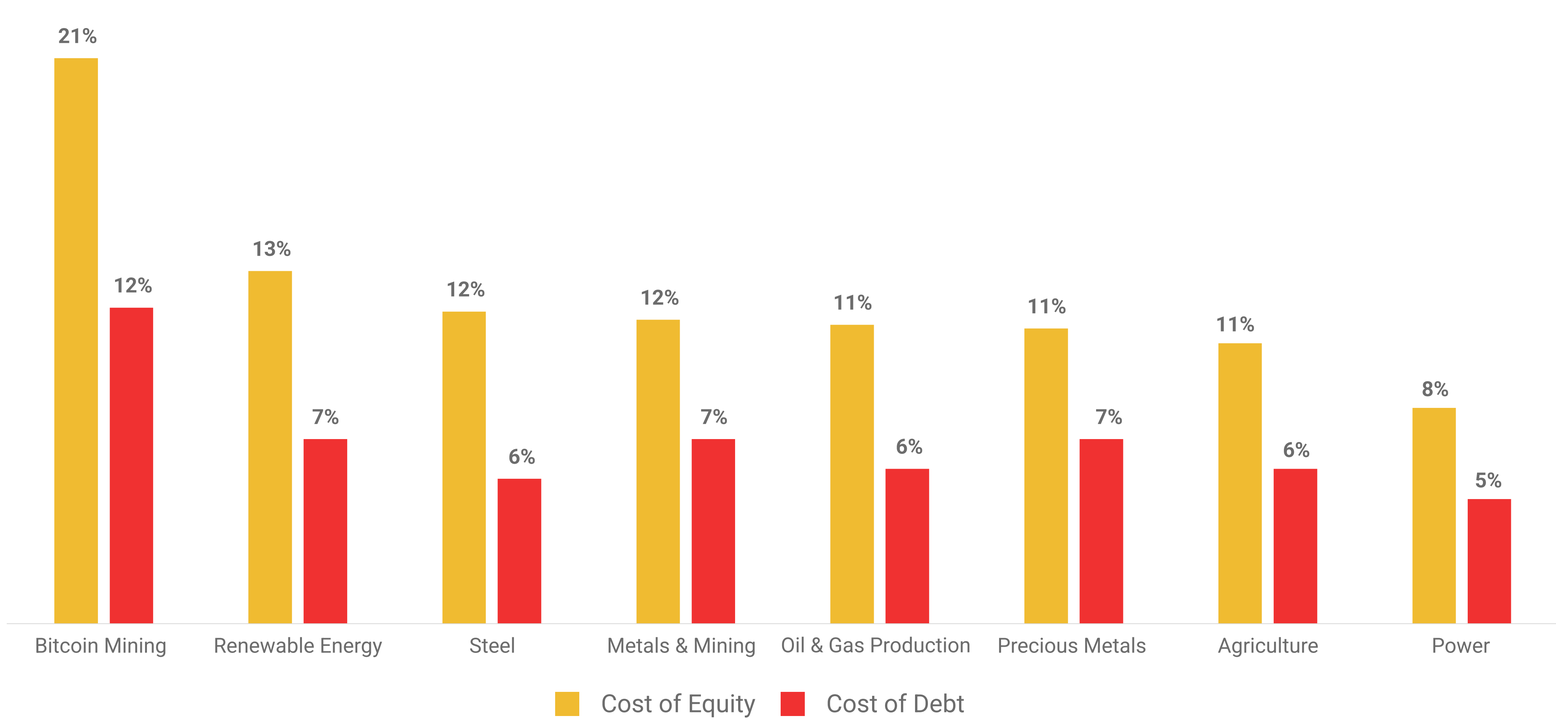
No Mention of Hedging / Unclear						
	Marathon	RIOT	Core Scientific	Greenidge	Bit Digital	Iris Energy

Source: Company websites, SEC, Sedar+, GSR. Note: Searches for the terms hedg, option*, derivative*, and risk management, and only includes discussions around hedging the price of bitcoin or network hashrate/difficulty. Uses annual regulatory filings per each company's jurisdiction (eg. US filers search 10-Ks; Canadian filers search annual AIF, financial statement and MD&A, etc). *TeraWulf 10-K also states "Incremental revenues may be generated through the hedging and sale of mined bitcoin" **Bitfarms also states "In the future, the Company may enter into certain hedging transactions to mitigate its exposure to aspects of the economy or specific economic conditions that are particularly volatile, including the market price of BTC and interest rates." ***Stronghold had previously entered into a variable prepaid forward sales contract derivative, and the 10K states "The Company also uses derivative instruments to mitigate the risks of Bitcoin market pricing volatility" though it appears they are not currently hedging given the above statement.*

Source: GSR

In traditional commodity sectors, the widespread use of hedging strategies reduces capital costs and enhances company valuations. However, Bitcoin mining, characterized by higher revenue volatility and limited hedging options, typically incurs increased capital costs. This heightened cost negatively affects valuations, fundraising, and the net income of Bitcoin mining companies.

Industries by Average Cost of Capital



Source: Stern NYU, Tradingview, The Miner Mag

Bid/ask spreads on Luxor's Hashrate Forward market widened during the transaction fee spikes in May-June and November-December 2023. Miners sought to secure higher transaction fee revenue, while buyers remained cautious about the duration of the fee surge. As the current fee spike seems more sustained, buyers are now factoring in higher transaction fees. This doesn't imply that buyers expect the current fee levels to persist indefinitely, but rather that they are willing to pay above pre-November levels, with no immediate return anticipated. In the ongoing fee bull run, miners can seize opportunities to sell their hashrate forward, locking in increased transaction fee hashprices. Simultaneously, buyers can capitalize on sustained high fees and upside volatility.

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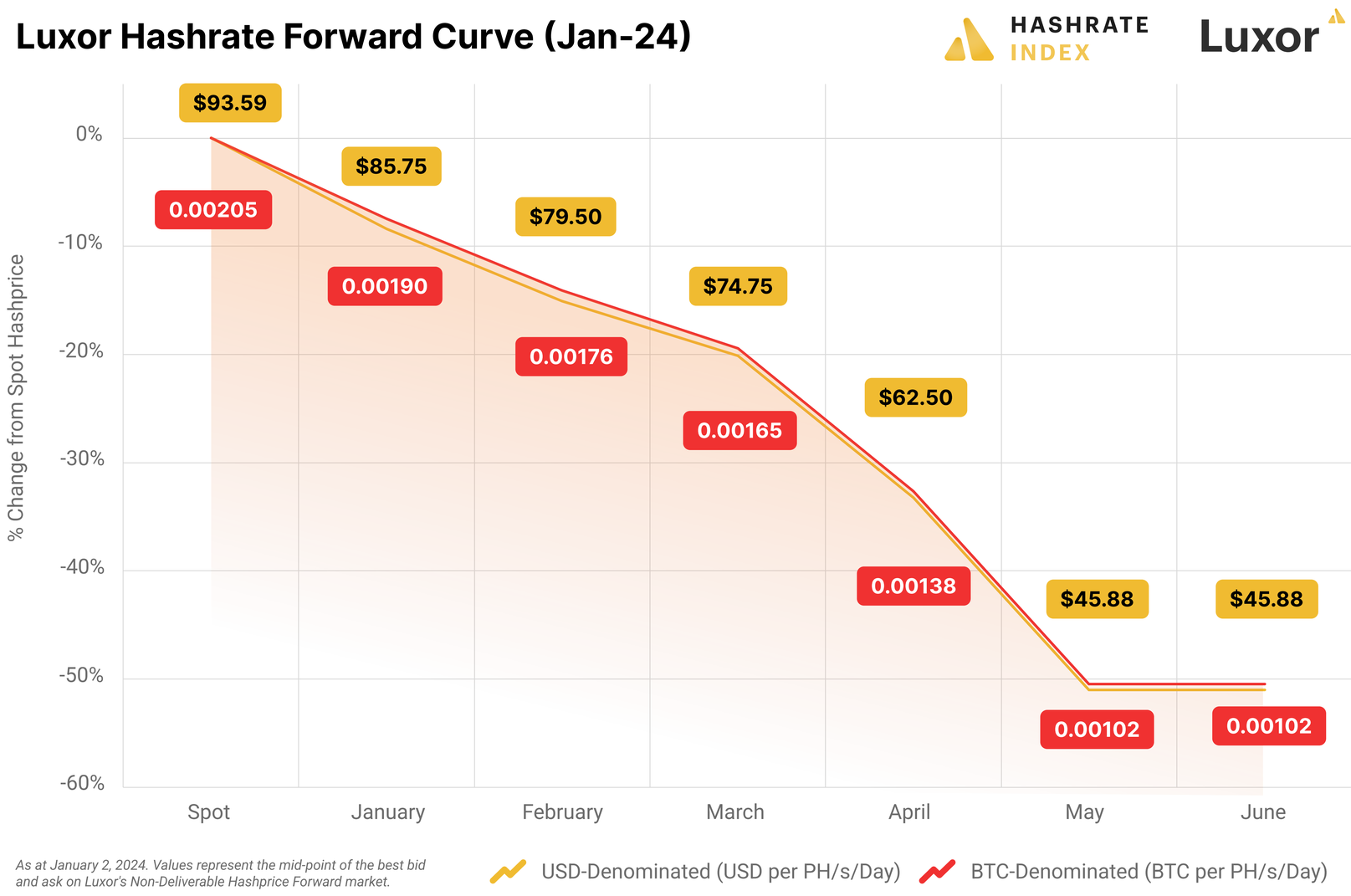
While the market matured considerably during 2023, arbitrage opportunities still exist between different hashrate marketplaces. We expect these prices to converge as they are arbitraged away by profitable and increasingly sophisticated traders.

At the time of writing, here is where forward hashprice markets are for the first half of 2024. As Luxor continues to onboard more institutional participants to its hashrate markets, including large public miners, crypto hedge funds, and new market makers, we anticipate much tighter spreads as well as deeper liquidity.



Source: Luxor Derivatives Desk

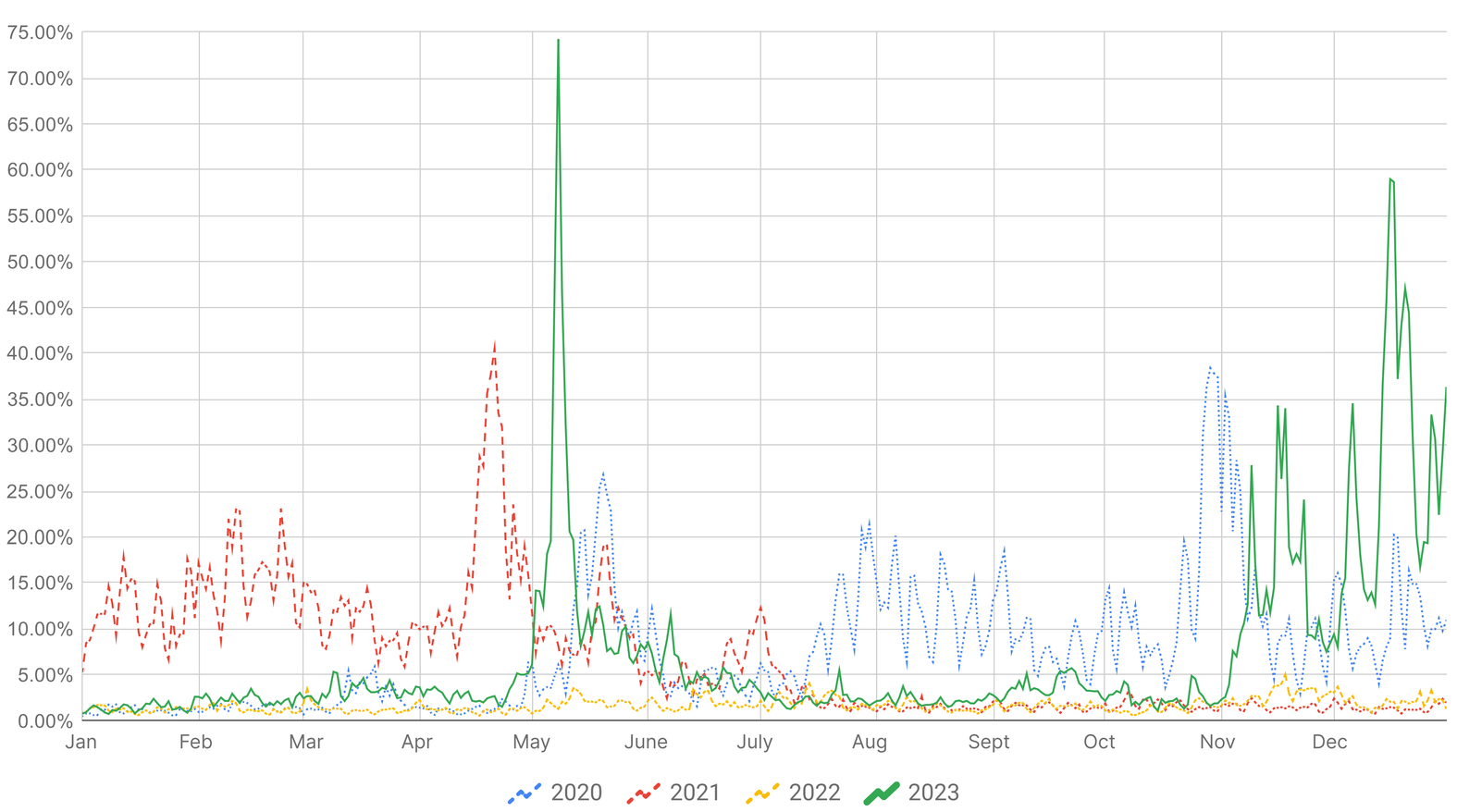
3

Inscriptions and Ordinals Juice Transaction Fees

The biggest dark horse of 2023 galloped into the market on the back of a new technical standard for Bitcoin-based non-fungible tokens (NFTs): ordinals and inscriptions. This new method for creating digital artifacts / art on Bitcoin revived transaction fees as a substantial source of mining revenue.

In fact, 2023 was the penultimate year for transaction fee rewards in Bitcoin's history; miners earned $797,867,915 in transaction fees in 2023, a haul that is second only to 2021's record of $1,019,725,113. Fees constituted 7.6% of block rewards in 2023, compared to 1.5% in 2022.

Transaction Fees as Percentage of Block Rewards

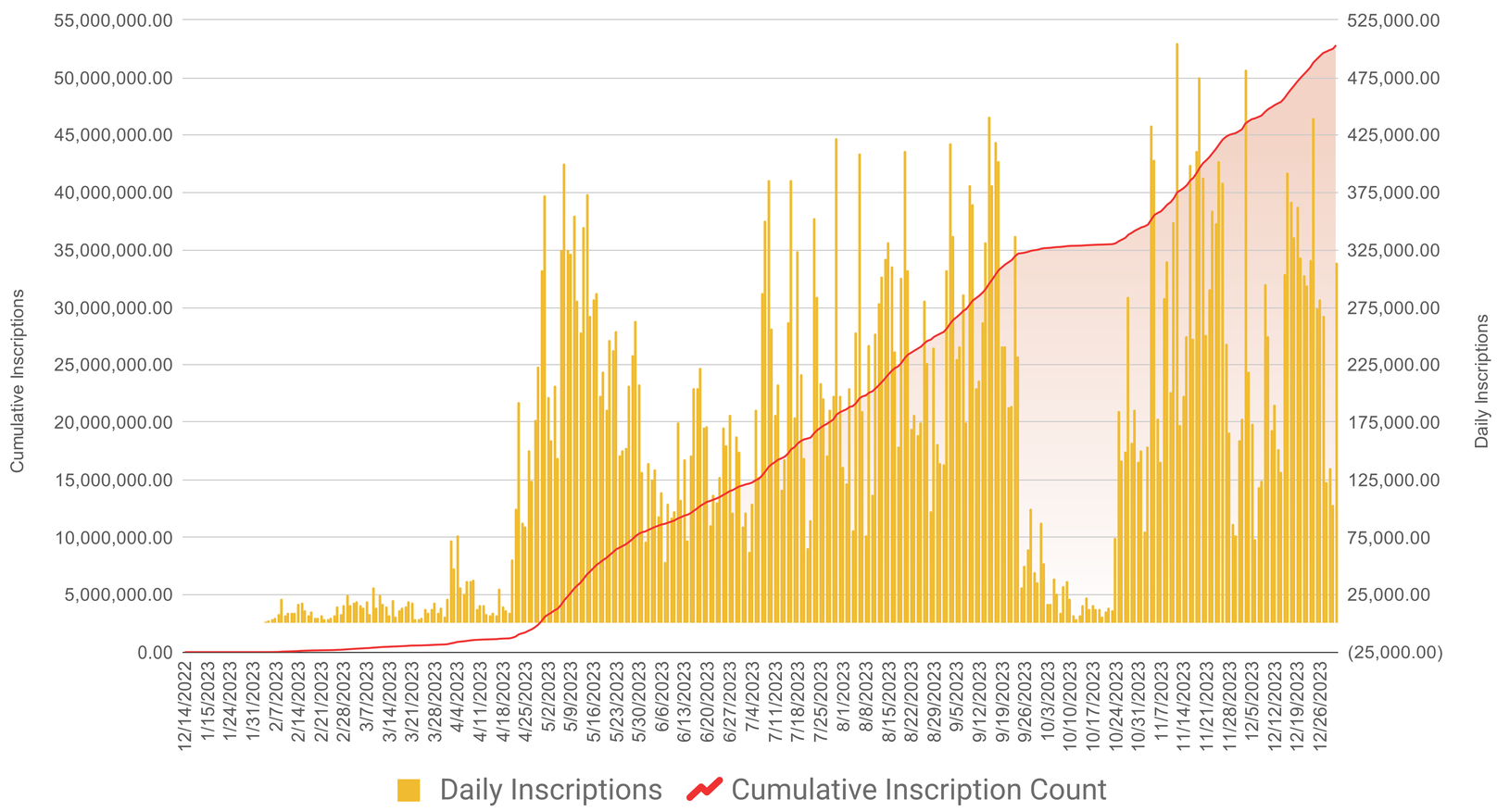


Source: Hashrate Index

The transaction fee bull market is all thanks to Bitcoin's incipient inscription market. Designed and first deployed by Bitcoin Developer Casey Rodarmor in December of 2022 inscriptions include digital images, videos, text, video game files (yes, really) – any arbitrary data that Bitcoin users can include in a Bitcoin transaction using specific transaction conditions. Unlike other NFTs on Ethereum, Solana, and other chains, where the file for the digital media for the NFT lives in a separate database, the media for these NFTs are actually uploaded on-chain to the arbitrary data space in Bitcoin's witness section. To track them, collectors use ordinal theory, the mathematics of sequencing, to mark a single satoshi in each transaction to act as the "deed" to the inscription. The Ordinal Theory traces each satoshi from the Genesis block using a first-in-first-out numerical scheme.

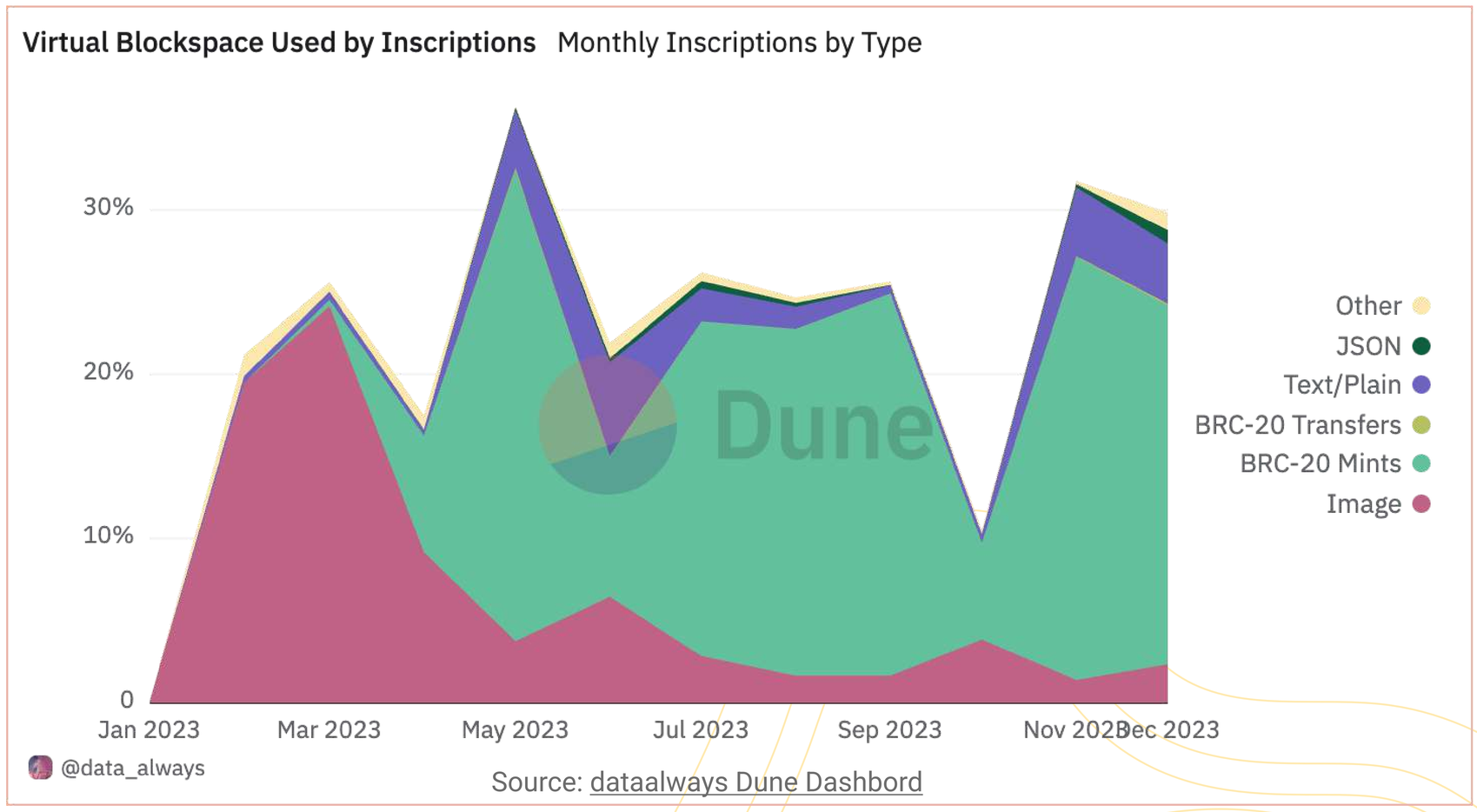
(For a more in-depth primer on ordinals and inscriptions, please consult this article for a 101 on inscriptions / ordinals and this article for how they have affected Bitcoin's blockspace and transaction fee markets).

Daily and Cumulative Inscriptions



Source: Hashrate Index

Inscription activity oscillated throughout the year, engendering the hashprice volatility we covered in the prior section. Inscription minting really ramped up in late April thanks to the advent of the BRC-20 standard (which we detail below), and it died down briefly throughout October, only to rise to its highest-ever levels in November and December. As of January 10 2024, inscribers (those who create inscriptions) have minted 54,162,332 inscriptions, and 45,805,220 (84.5%) of these have been BRC-20 tokens, according to dataalways' Dune dashboard.



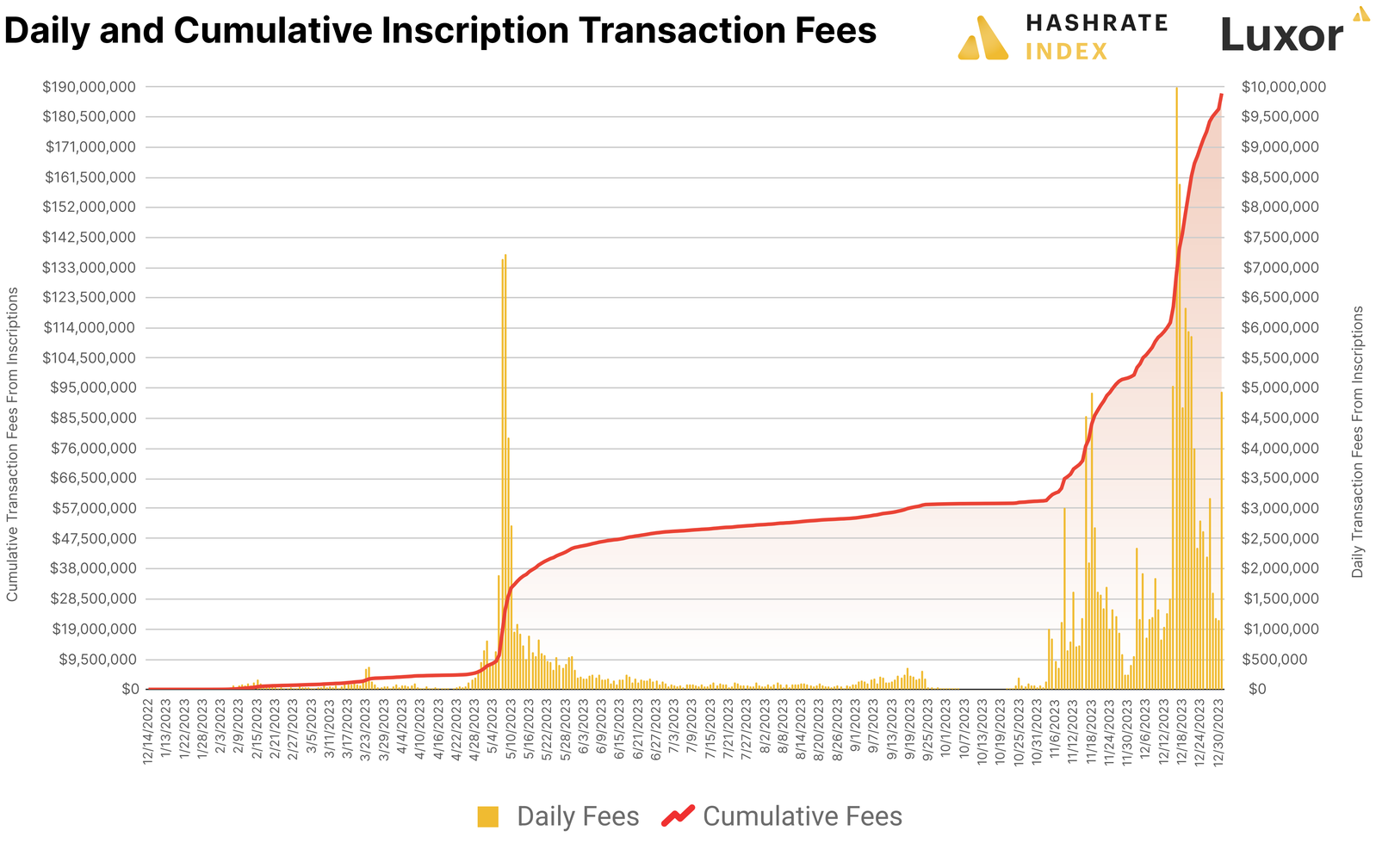
Source: dataalways Dune Dashbord

The fee glut that these inscriptions cooked up has been nearly unprecedented. **As a result of their adoption, in May 2023, Bitcoin miners reaped their highest daily average fees as a percentage of block rewards since 2017 – a 74% haul that was just under December 22, 2017's all-time high of 77%. Inscriptions delivered their highest level of transaction fees ($10 million) on December 16, 2023.**

While May brought a high in transaction fees as a percentage of block rewards, transaction fees in Q4 were consistently elevated as a result of inscriptions for the longest period since the advent of the NFT standard to Bitcoin. **In fact, of the $188 million in transaction fees that inscriptions generated over 2023 since December 2022, miners accrued $129.5 million (69%) of these fees in Q4 2023. Going further, miners generated 63% of 2023's total transaction fee rewards ($501.8 million) in Q4.**

As the chart below illustrates, cumulative fees from inscriptions took off in Q4-2023 and more than doubled over the course of the quarter.

Daily and Cumulative Inscription Transaction Fees



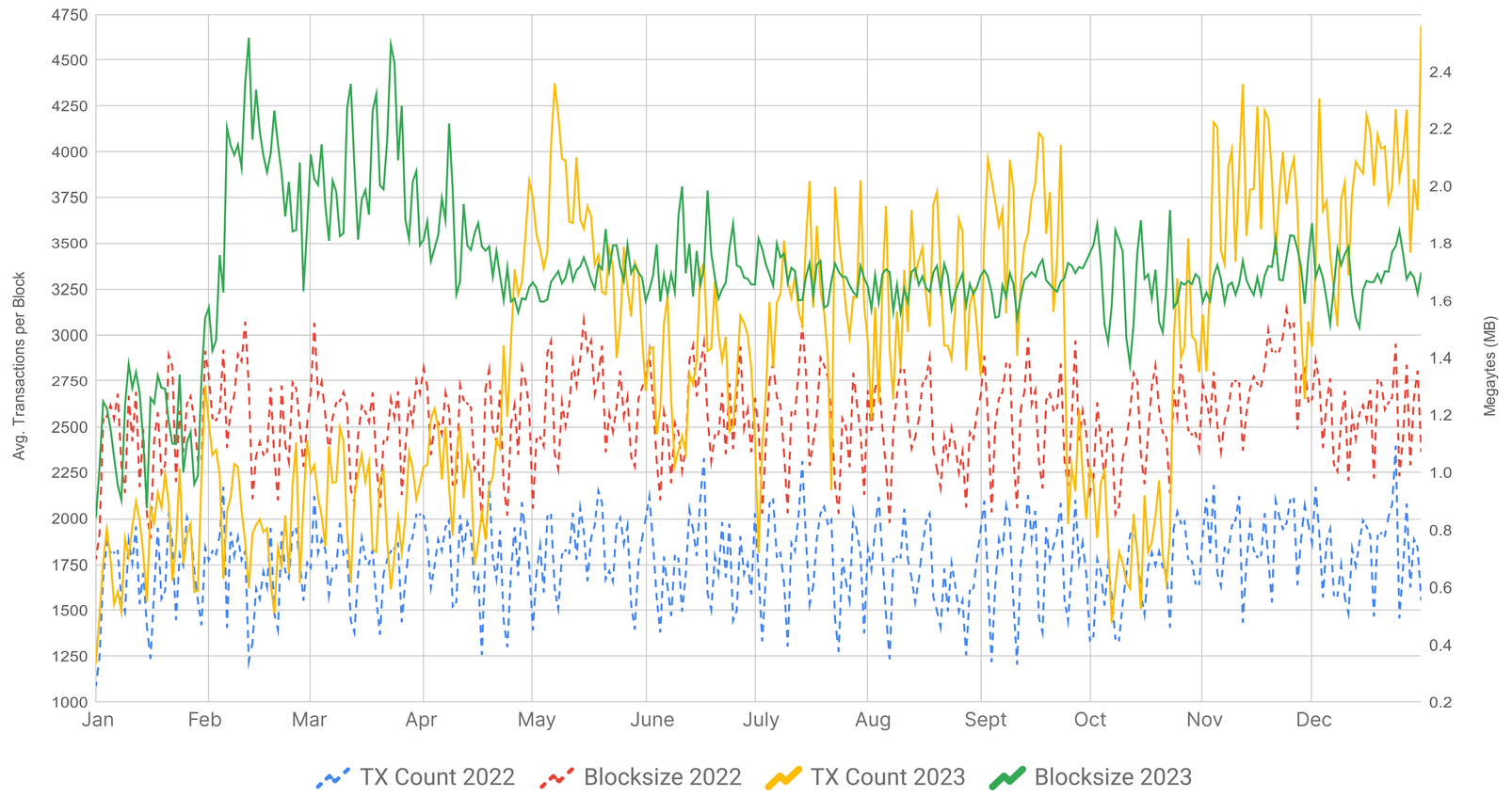
Source: dataalways Dune Dashbord

The Anatomy of Blockspace: Dissecting the Impact of Inscriptions on Block Sizes

Inscriptions have been controversial for a number of reasons, not least of which because they benefit from SegWit's data discount. The data for the inscription lives in the transaction witness section of a block that was introduced with 2017's Segregated Witness (SegWit) upgrade. Witness data is cheaper to transact per byte than data included elsewhere in the transaction, so inscriptions cost fewer satoshis per byte of data than a typical financial transaction.

We can observe the SegWit discount in full effect in the chart below: the gap between transaction counts and block sizes from February to May best demonstrates the witness discount's impact on early inscription fee dynamics. Blocks were filling up with arbitrary inscription data like images and text, but the transaction count – increase though it did – did not increase astronomically.

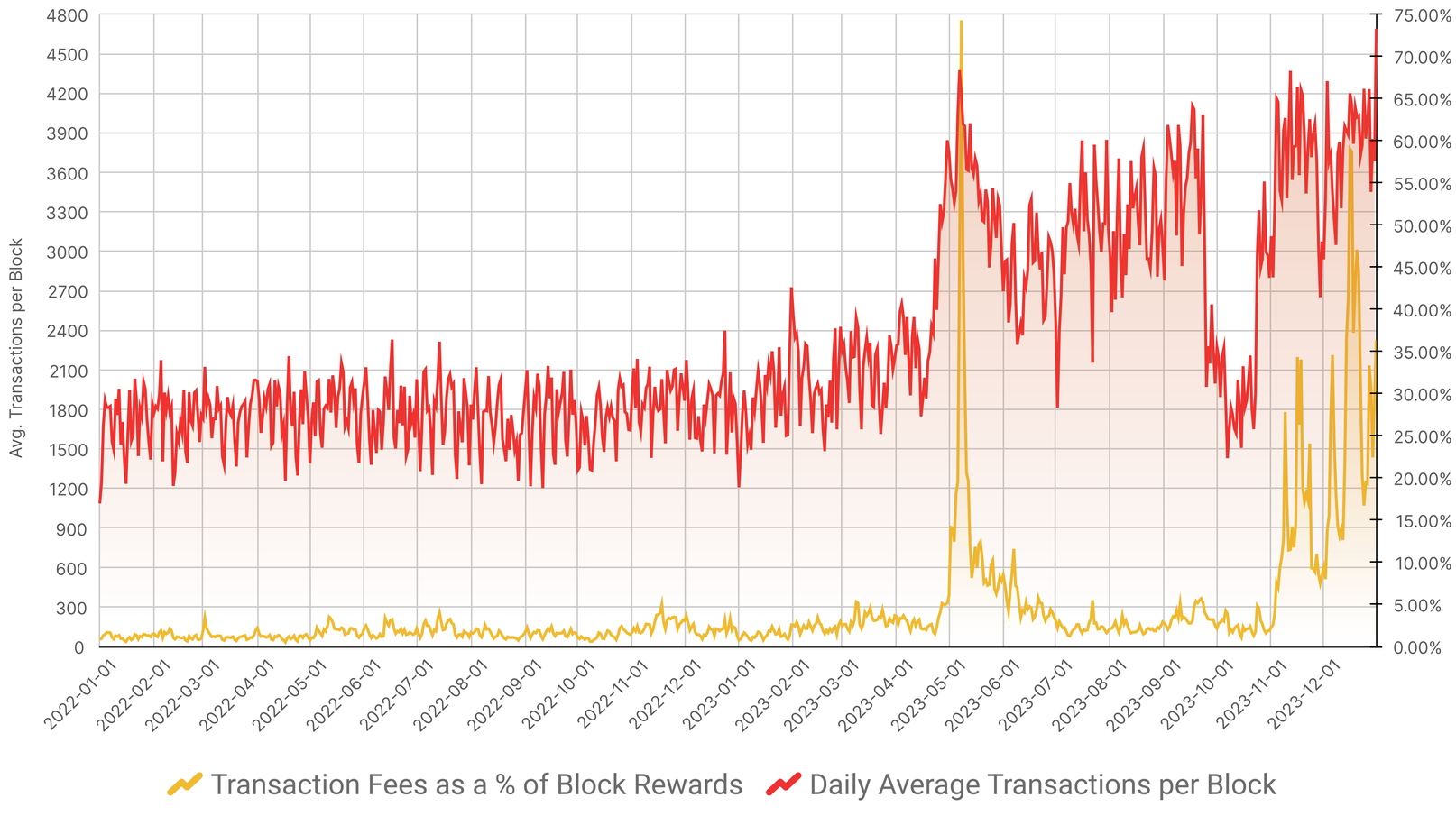
Average Daily Transaction Count and Average Daily Block Size (2022 vs. 2023)



Source: Hashrate Index

Transaction counts (and with them, transaction fees) don't really take off until late April and May with the introduction of BRC-20 tokens. The first wave of inscriptions were mostly jpegs and other image formats that benefited greatly from the discount, but BRC-20 transactions benefit less from the discount, and they incentivize an entirely different level of trading activity. The adoption of BRC-20 inscription minting progressively increased transaction volumes throughout 2023 and fees with it, as demonstrated in the chart below.

Transaction Fees as a Percentage of Block Rewards vs. Daily Avg. Transactions



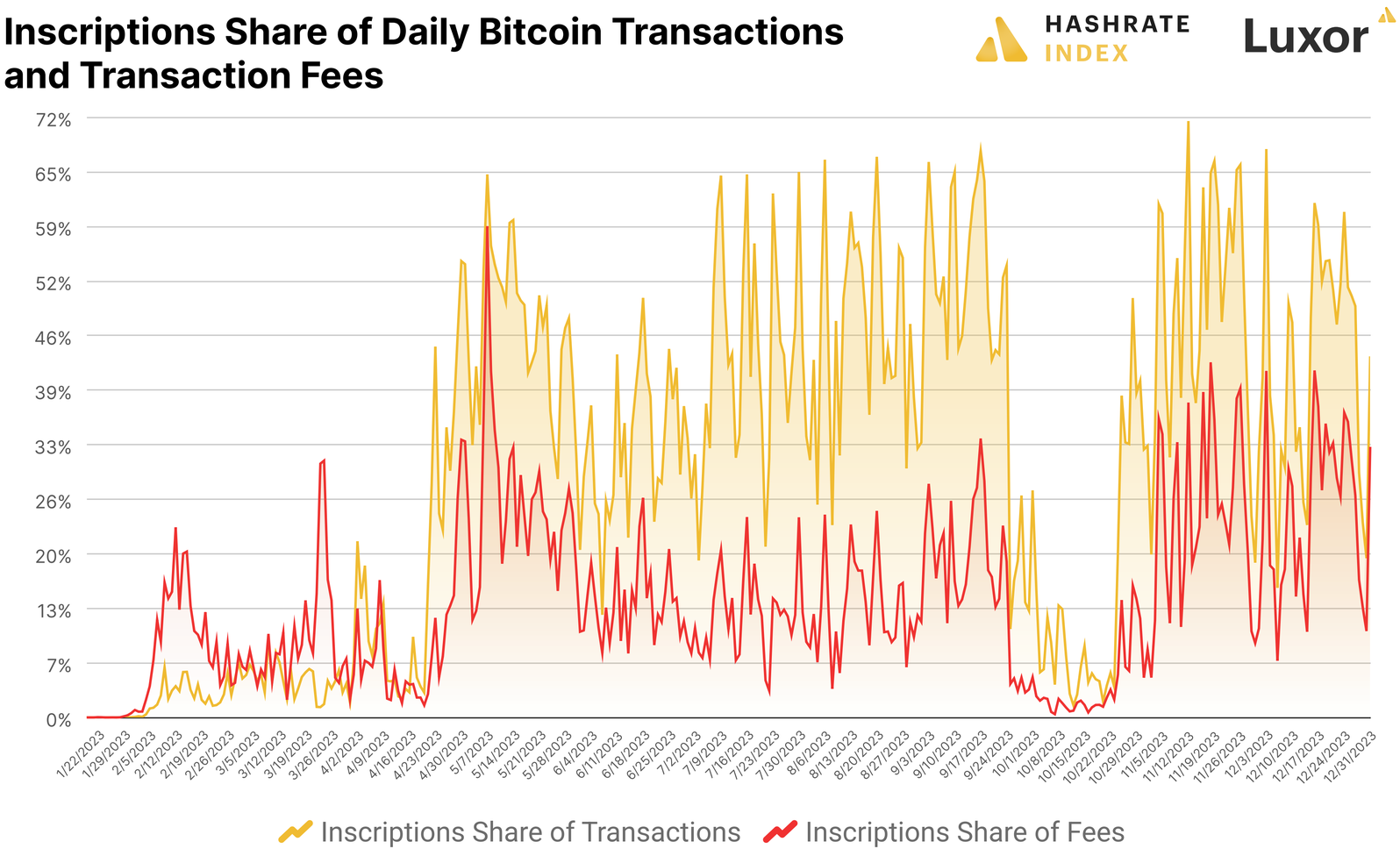
Source: Hashrate Index

The BRC-20 standard finally brought Ethereum-like minting incentives to the inscriptions landscape. Before, inscribers would mint an entire collection and then auction off these images in a very basic, OTC fashion in Discord servers, on Twitter, and other forums; unlike popular NFT collections on other chains like Ethereum and Solana, where users could mint their own NFTs from minting events via smart contracts, this option did not exist for inscription collectors.

The BRC-20 standard changed this. Now, using Bitcoin's OP_CODE field, collection creators can create a token parameter with a set supply. After they broadcast the template, anyone can mint tokens in the series if they follow the token's parameters. This first-come-first-mint mechanism incentivizes inscribers to bid up fees to be the first to mint a new series. This minting incentives (and the fact that BRC-20 transactions don't benefit greatly from the SegWit discount) make BRC-20 inscriptions the primary driver of 2023's transaction fee boom.

As we noted earlier in this chapter, inscription activity reached a fever pitch in Q4 of 2023. **Inscription as a share of all transactions hit a high of 72% on November 12, 2023. The average share of transaction fees from inscriptions was 17% in Q4-2023, versus 14% in Q3, 16% in Q2, and 8% in Q1. As of January 10, 2024, BRC-20 tokens have generated $152,533,796 in transaction fees, which is 78% of all-time inscription transaction fee spending ($195,906,821).**

Inscriptions Share of Daily Bitcoin Transactions and Transaction Fees

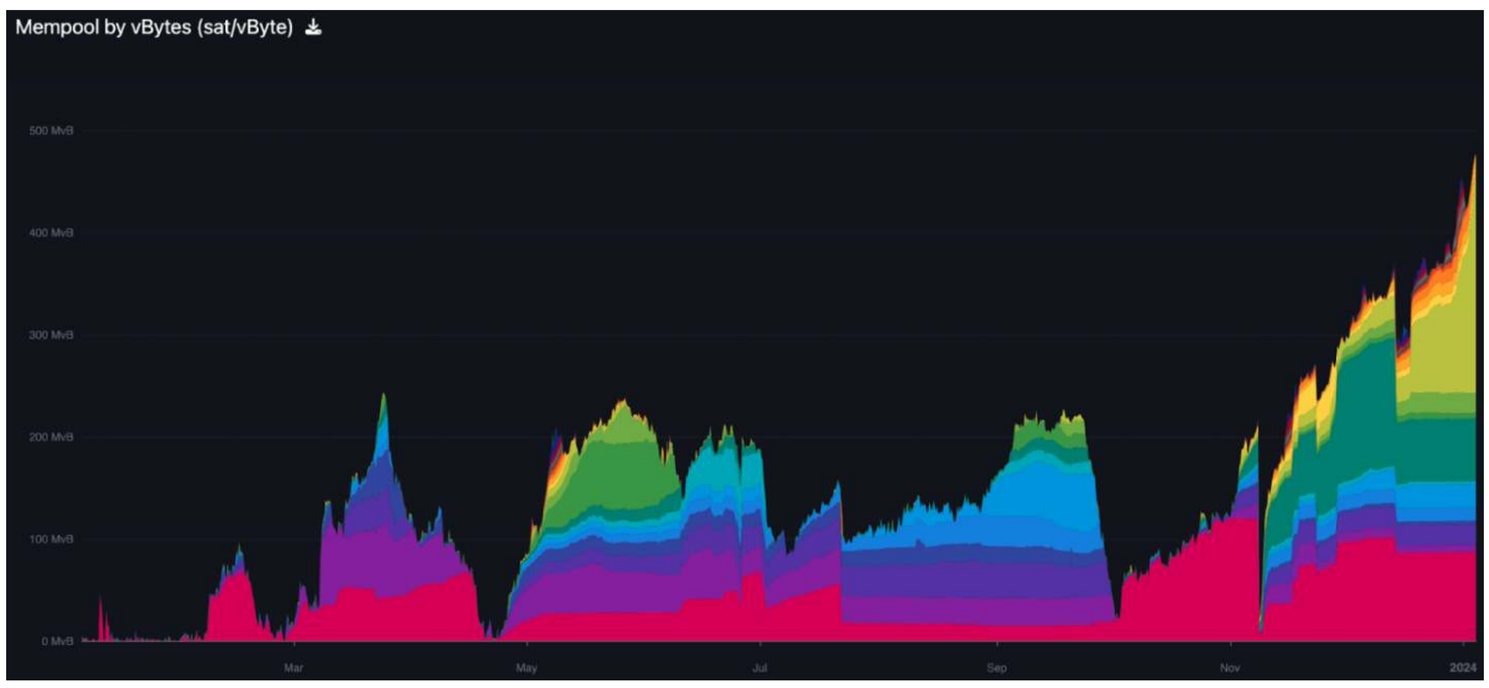


Source: dataalways Dune Dashbord, Coin Metrics, Hashrate Index

Direct and Indirect Fee Pressure from Inscriptions

To understand how inscriptions impact blockspace dynamics and Bitcoin's transaction fee market, we need to look beyond the "direct" pressure that inscriptions assert on transaction fees. We need to understand how inscriptions insert "indirect" pressure on transaction fees by creating congestion in Bitcoin's global transaction queue.

High BRC-20 activity first cropped up in May, so much so that the average transactions included in each block reached an all-time high; BRC-20 mania (among other inscription influences) resurfaced in the last two months of the year, sending transaction fees on their most continuous run for 2023. The mad-dash to mint these text-based inscriptions clogged Bitcoin's mempool (the queue for unconfirmed transactions). The mempool was consistently congested in 2023, with the total volume for unconfirmed transactions hitting an all-time high in December 2023.

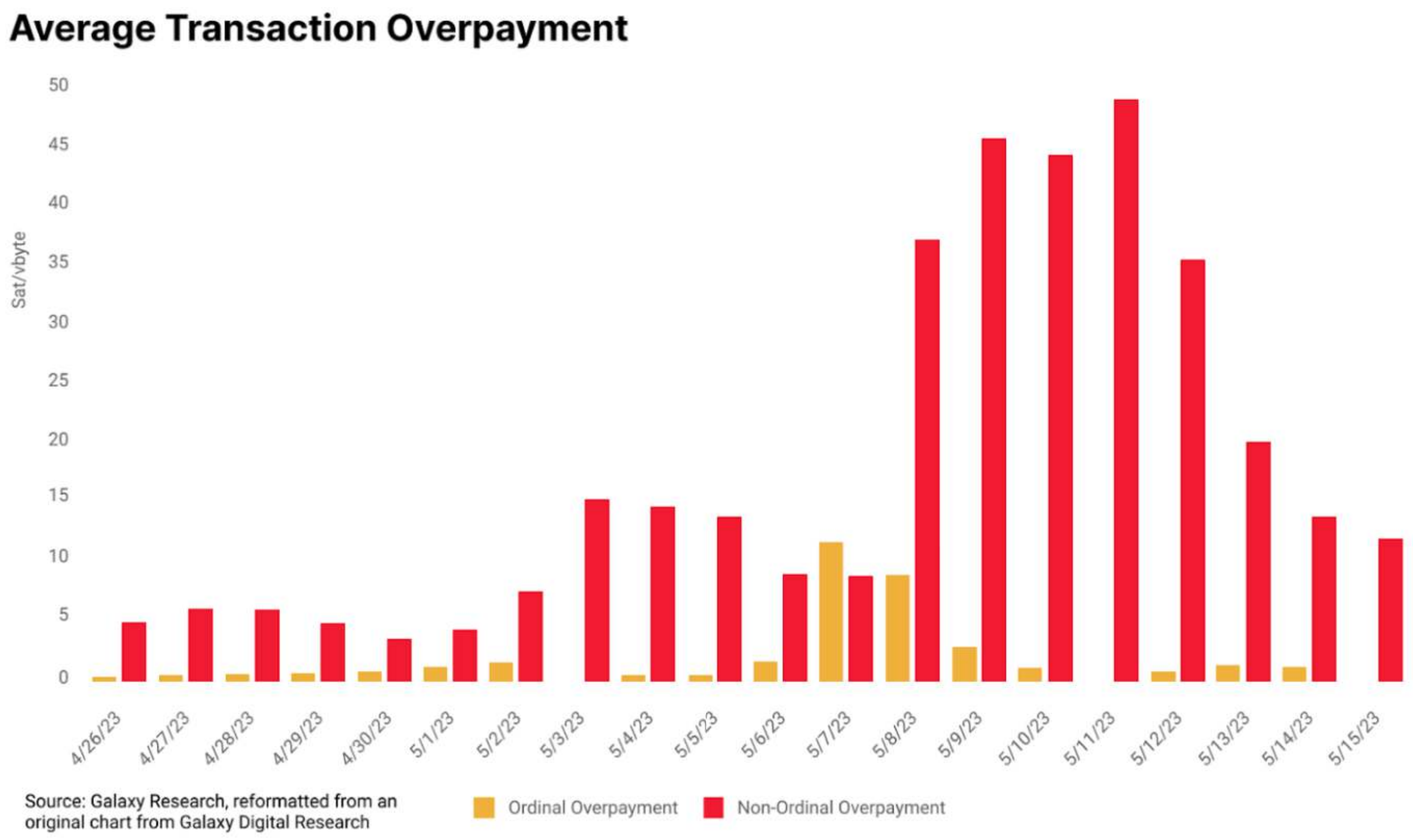


Source: Mempool.space

Notably, the transaction backlog that inscription activity created throughout 2023 exerted roundabout pressure on transaction fees. We call this "indirect" fee pressure to differentiate between fees generated from inscription transactions ("direct" fee pressure) and fees generated from other transactions during times of inscription-led mempool congestion; "indirect" fee pressure comes from users who pay higher fees for normal, financial transactions than they would otherwise be paying if inscription activity didn't create a transaction backlog in the mempool.

As Galaxy Digital points out in a 2023 report on ordinals/inscriptions, mempool congestion precipitated transaction fee "overpayment" from various transactors. The Galaxy Digital Research team defines overpayment as any transaction fee in a block greater than that block's median transaction fee (in sats/vbyte). For financial transactions (i.e., normal BTC transfers), this overpayment could stem from inaccurate transaction fee estimators in wallet / exchange software or from general user ignorance regarding transaction fee structure and dynamics. Additionally, some financial transactions may have been time sensitive, so users overbid their fees to expedite their transactions during mempool congestion. For inscription transactions, this so-called "voluntary overpayment" was commonplace during times of high activity and popular mints, particularly for BRC-20 tokens whose first-come-first-mint design encourages such behavior.

The chart below quantifies overpayment for inscription/ordinal transactions and all other transactions to demonstrate the dynamics discussed above. As the chart suggests, when Bitcoin's mempool became backlogged in April and May, a majority of the transaction fees during this time actually came from user overpayment for financial transactions – not inscriptions/ordinals themselves.



This insight is important for understanding that inscriptions create bother direct and indirect pressure on transaction fees. We define direct pressure as transaction fees that users pay for inscription transactions, while indirect pressure comes from the impact inscriptions have on block space dynamics by driving other users to overpay for block space. Overall, indirect and direct transaction fee pressures from inscriptions are important for understanding how inscription activity can raise the transaction fee floor.

For more analysis and data exploring inscription transaction fee dynamics, we highly recommend Galaxy Digital Research's report linked on the prior page.

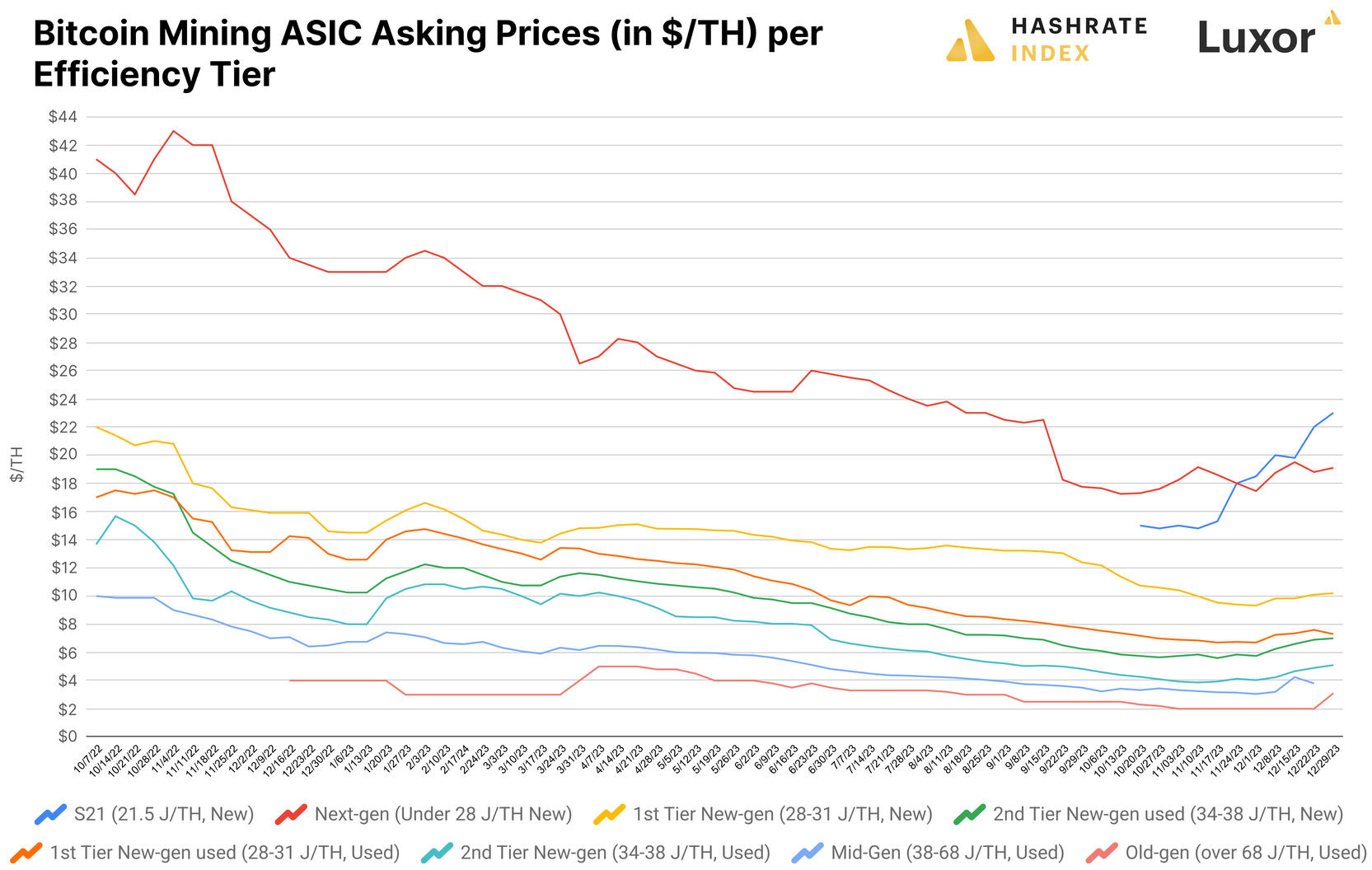
4

ASIC Market Finds a Bottom

ASIC miner prices entered 2023 in a downtrend. That downtrend finally found a bottom in Q4-2023.

ASIC prices popped from 2022's lows in the first quarter of 2023 as Bitcoin's price recovered from $16,000, only to continue to backslide through Q2 and Q3 after their brief price recovery at the beginning of the year. (It's worth noting that the gradual rise in hashprice over 2023 kept valuations higher than they would have been). For now at least, next-gen ASIC prices hit lows in October and new-gen ASICs hit lows in late November / early December; since then, they've bounced in response to Q4's impressive hashprice rally.

The chart below shows asking prices in dollars per terahash for different efficiency tiers of Bitcoin mining ASICs. Notably, as the delivery dates for the first batch of S21s and the Fourth Halving draw closer, prices for this latest model have increased significantly. S21 orders are cutting into pricing for other next-gen rigs like the S19 XP, M60, and S19k Pro, and they are even more significantly impacting prices for new-gen rigs.



Source: Luxor ASIC Trading Desk

Looking at prices for tiers below the S21 and other next-gen ASICs, 1st tier new-gen ASICs (rigs with an efficiency of 28-31 J/TH) gradually separated from the pack over 2023. Premiums for 1st tier new-gen ASICs began gradually increasing over older and used models in April, and the spread only recently started contracting after the introduction of the S21.

The chart above also indicates a notable trend regarding ASIC efficiencies, **namely that even used 1st tier new-gen rigs carried a premium over NEW 2nd tier new-gens (rigs with an efficiency of 32-38 J/TH) for most of 2023.** Last year, miners prioritized efficiency over condition – put differently, they would rather take a machine that is used with an efficiency of 30 J/TH than one that is new with a 34 J/TH rating.

It appears as though 2nd tier new-gen rigs were oversold throughout 2023, as evidenced by the pop in price they experienced in Q4-2023. Old-gen rigs experienced the least reduction in listing prices over 2023, but this data should be taken with a grain of salt given the general dearth of data points for this class and the fact that such ASICs were already dirt cheap at the beginning of 2023. Excluding old-gen rigs from the set, we see that new 1st tier new-gen rigs and new 2nd tier new-gen rigs respectively experienced the first and second smallest reduction in asking prices over 2023. Mid-gen rigs saw the largest reduction in price, followed notably by next-gen rigs, which seem to have been largely overpriced for much of 2023 and which are now being repriced in light of the S21's release.

Listing Prices 2023 per Efficiency Tier	Q1 change	Q2 Change	Q3 change	Q4-Changes	Yearly Change
S21 (17.5 J/TH) New	-	-	-	53.33%	-
Next-gen (Under 28 J/TH) New	-19.70%	-4.63%	-30.39%	8.22%	-42.12%
1st Tier New-gen (28-31 J/TH) New	2.16%	-9.98%	-6.51%	-16.22%	-29.66%
2nd Tier New-gen (34-38 J/TH) New	13.41%	-20.43%	-28.57%	14.75%	-31.71%
1st Tier New-gen (28-31 J/TH) Used	6.29%	-25.38%	-17.29%	-3.10%	-41.99%
2nd Tier New-gen (34-38 J/TH) Used	25.00%	-32.52%	-27.14%	10.87%	-36.25%
Mid-gen (38-69 J/TH) Used	-8.64%	-25.39%	-25.00%	17.53%	-43.70%
Old-gen (Over 68 J/TH) Used	-	-30.00%	-24.24%	24.00%	-22.50%

Source: Luxor ASIC Trading Desk

In 2023, top ASIC manufacturers unveiled new ASIC series. Bitmain released its Antminer S21 and T21, and MicroBT unveiled its Whatsminer M60 series. These new models were the first ever to feature sub-20 J/TH efficiency ratings, and they will no doubt be instrumental for miners to survive the Halving, especially those with higher cost power. In addition to their latest ASIC series, Bitmain and MicroBT also released new models in existing series, like the S19j XP, M50s++, and S19k Pro.

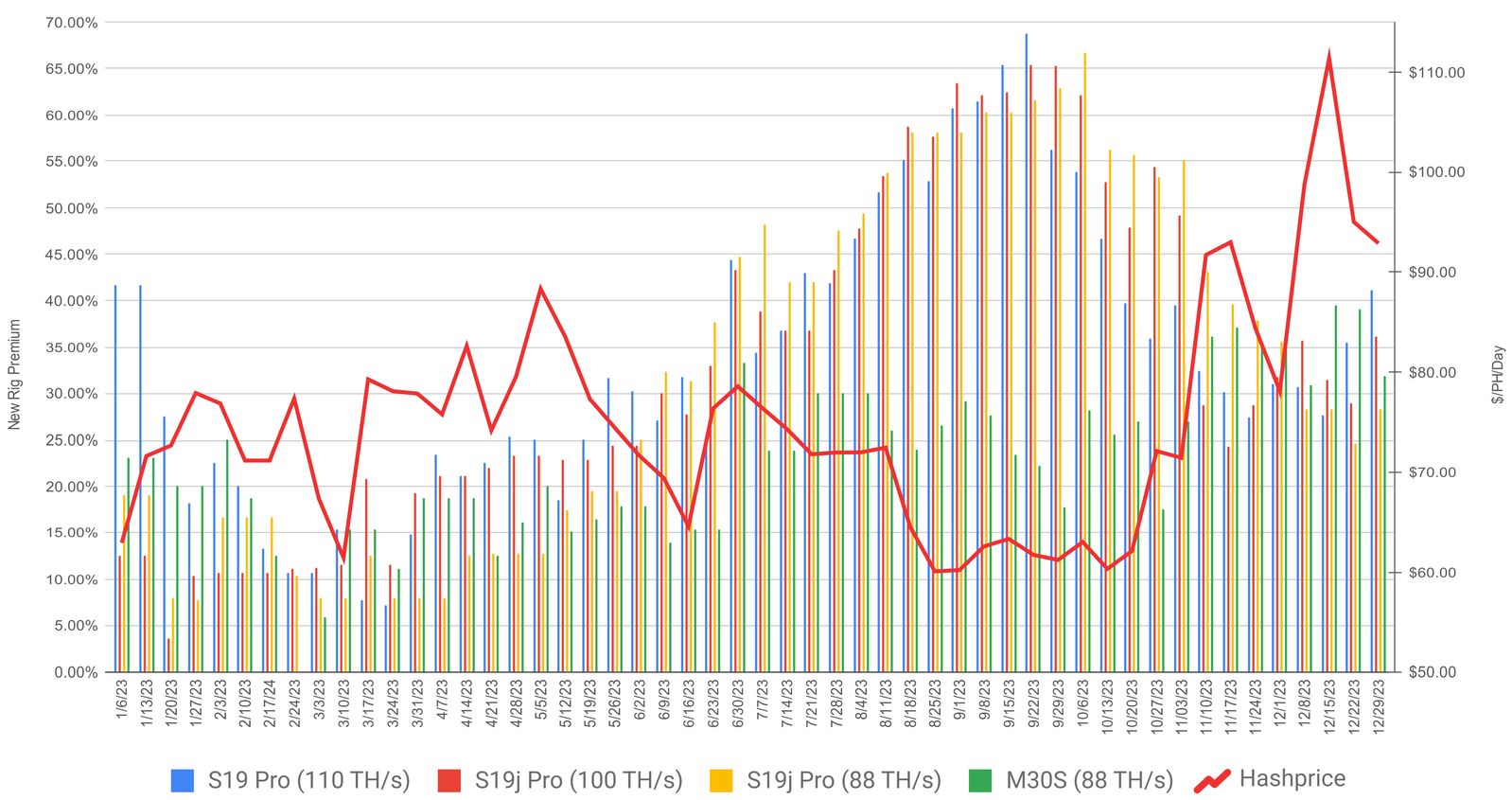
Bitcoin Mining ASICs	Hashrate	Efficiency	Wattage
Antminer S21	200 TH/s	17.5 J/TH	3500 W
M60S	186 TH/s	18.5 J/TH	3441 W
T21	190 TH/s	19 J/TH	3610 W
M60	162 TH/s	19.2 J/TH	3104 W
S19j XP	151 TH/s	21.5 J/TH	3247 W
M50s++	150 TH/s	22 J/TH	3300 W
S19k Pro	120 TH/s	23.0 J/TH	2760 W

Source: Hashrate Index

New vs Used ASIC Premiums Rise

Taking a close look at new and used ASIC models, we can see that premiums for new ASIC models rose as 2023 wore on. The chart below shows the percentage difference in $/TH between new and used ASIC from 1-200 MOQ orders from Luxor's ASIC Trading Desk market data.

Price Premium for New vs Used ASIC Miners vs. Hashprice



Source: Luxor ASIC Trading Desk

These premiums increased significantly in the middle of the year (and in Q3 in particular) as hashprice crept down to all-time low territory. Premiums for new hardware decreased in Q4 as hashprice rallied, but even so, they closed 2023 higher than they opened. As the halving approaches, it's clear the miners are preferring new equipment over used; that said, the discount afforded to used machines could present attractive opportunities for miners with the right operating expenses, or they could be a worthwhile trade if bitcoin continues its price run.

2023 Avg. New vs. Used Premiums	Q4	Q3	Q2	Q1
S19 Pro (110 TH/s)	36.27%	51.94%	26.97%	19.35%
S19j Pro (100 TH/s)	39.42%	53.26%	26.11%	12.05%
S19j Pro (88 TH/s)	42.55%	54.03%	22.00%	12.21%
M30S (88 TH/s)	31.57%	25.72%	17.81%	16.07%

Source: Luxor ASIC Trading Desk

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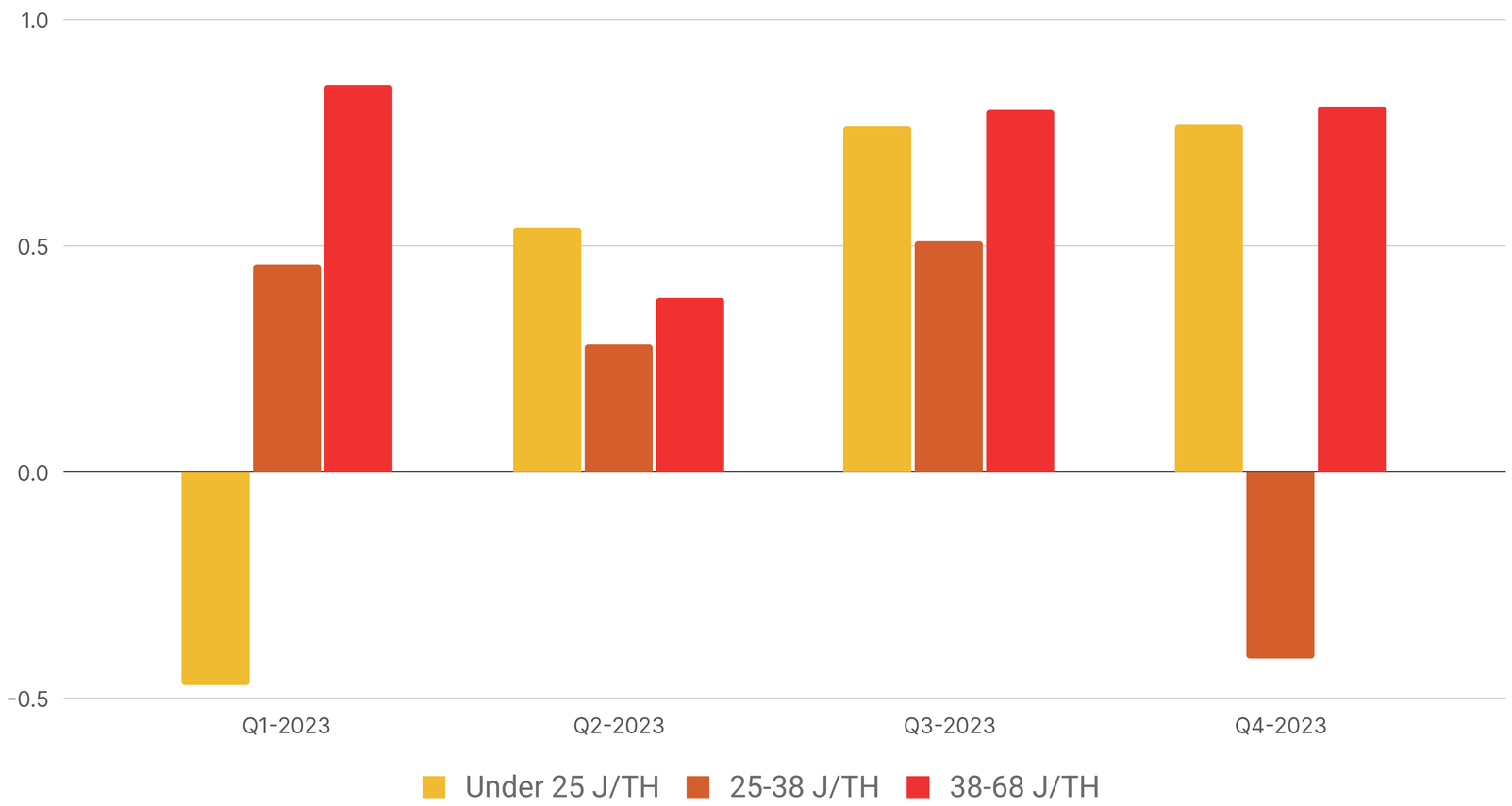
ASIC Correlations to Bitcoin Price per Quarter

We saw a strong correlation for mid-generation (38-68 J/TH) machines with the price of bitcoin throughout the year, while next-generation (under 25 J/TH) machines correlated negatively to bitcoin in Q1-2023 and new-generation (25-38 J/TH) correlated negatively to bitcoin in Q4-2023. These correlations serve as a reminder that ASIC prices are determined by myriad factors -- principally supply and demand -- rather than solely mining economics or BTC price. On this note, the negative correlation in Q1-2023 for next-gen rigs likely comes from the fact that miners demanded these rigs over other, older models at a time when hashprice was compressed (the average hashprice in Q1-2023 was $73/PH/day).

ASIC Price Correlation to Bitcoin Price



Source: Luxor ASIC Trading Desk, Hashrate Index

Breakeven Analysis per ASIC Model

As we look ahead to the halving, it's prudent to examine the breakeven power power prices of various rigs under different hashprice scenarios.

The table below shows the $/kWh breakeven cost of popular Whatsminer and Bitmain mining rigs according to hashprice scenarios that range from $125/PH/day down to $20/PH/day.

The table demonstrates what is perhaps obvious to most: next-generation rigs could be instrumental to surviving next year's block subsidy reduction. Lets assume, for instance, that hashprice is $45/PH/day following the halving (i.e., half of Q4-2024's average hashprice of $90/PH/day). Under this scenario, the breakevens for next-gen rigs are as follows (in $/kWh): S21 ($0.107), M60S ($0.101), M60 ($0.098), S19j XP ($0.087), M50S++ ($0.085), S19 XP ($0.083), S19k Pro ($0.082), M50S+ ($0.078), M50 ($0.072), S19j Pro+ ($0.068). Now compare that to the breakevens for new-gen rigs: M50 ($0.065), S19 Pro ($0.063), S19j Pro ($0.061), M30s+ ($0.055), S19 ($0.055), M30 ($0.049). To put these breakevens into perspective, consider the average industrial power cost in the US from January through October 2023 ($0.0813/kWh) and the average Bitcoin mining hosting cost in the US in 2023 from our hosting index ($0.078/kWh).

Breakeven Power ($/kWh) per Hashprice ($/PH/day)																						
Model	**$125**	**$120**	**$115**	**$110**	**$105**	**$100**	**$95**	**$90**	**$85**	**$80**	**$75**	**$70**	**$65**	**$60**	**$55**	**$50**	**$45**	**$40**	**$35**	**$30**	**$25**	**$20**
S21 (200 TH/s | 17.5 J/TH)	$0.298	$0.286	$0.274	$0.262	$0.250	$0.238	$0.226	$0.214	$0.202	$0.190	$0.179	$0.167	$0.155	$0.143	$0.131	$0.119	$0.107	$0.095	$0.083	$0.071	$0.060	$0.048
M60S (186 TH/s | 18.5 J/TH)	$0.282	$0.270	$0.259	$0.248	$0.236	$0.225	$0.214	$0.203	$0.191	$0.180	$0.169	$0.158	$0.146	$0.135	$0.124	$0.113	$0.101	$0.090	$0.079	$0.068	$0.056	$0.045
M60 (162 TH/s | 19.2 J/TH)	$0.272	$0.261	$0.250	$0.239	$0.228	$0.217	$0.207	$0.196	$0.185	$0.174	$0.163	$0.152	$0.141	$0.130	$0.120	$0.109	$0.098	$0.087	$0.076	$0.065	$0.054	$0.043
S19j XP (151 TH/s | 21.5 J/TH)	$0.242	$0.233	$0.223	$0.213	$0.203	$0.194	$0.184	$0.174	$0.165	$0.155	$0.145	$0.136	$0.126	$0.116	$0.107	$0.097	$0.087	$0.078	$0.068	$0.058	$0.048	$0.039
M50S++ (150 TH/s | 22 J/TH)	$0.237	$0.227	$0.218	$0.208	$0.199	$0.189	$0.180	$0.170	$0.161	$0.152	$0.142	$0.133	$0.123	$0.114	$0.104	$0.095	$0.085	$0.076	$0.066	$0.057	$0.047	$0.038
S19 XP (134 TH/s | 21.5 J/TH)	$0.232	$0.223	$0.213	$0.204	$0.195	$0.185	$0.176	$0.167	$0.158	$0.148	$0.139	$0.130	$0.121	$0.111	$0.102	$0.093	$0.083	$0.074	$0.065	$0.056	$0.046	$0.037
S19k Pro (120 TH/s | 23 J/TH)	$0.226	$0.217	$0.208	$0.199	$0.190	$0.181	$0.172	$0.163	$0.154	$0.145	$0.136	$0.127	$0.118	$0.109	$0.100	$0.091	$0.082	$0.072	$0.063	$0.054	$0.045	$0.036
M50S+ (136 TH/s | 24 J/TH)	$0.217	$0.208	$0.200	$0.191	$0.182	$0.174	$0.165	$0.156	$0.148	$0.139	$0.130	$0.122	$0.113	$0.104	$0.095	$0.087	$0.078	$0.069	$0.061	$0.052	$0.043	$0.035
M50S (126 TH/s | 26 J/TH)	$0.200	$0.192	$0.184	$0.176	$0.168	$0.160	$0.152	$0.144	$0.136	$0.128	$0.120	$0.112	$0.104	$0.096	$0.088	$0.080	$0.072	$0.064	$0.056	$0.048	$0.040	$0.032
S19j Pro+ (122 TH/s | 27.5 J/TH)	$0.189	$0.182	$0.174	$0.167	$0.159	$0.152	$0.144	$0.136	$0.129	$0.121	$0.114	$0.106	$0.098	$0.091	$0.083	$0.076	$0.068	$0.061	$0.053	$0.045	$0.038	$0.030
M50 (114 TH/s | 29 J/TH)	$0.180	$0.172	$0.165	$0.158	$0.151	$0.144	$0.136	$0.129	$0.122	$0.115	$0.108	$0.101	$0.093	$0.086	$0.079	$0.072	$0.065	$0.057	$0.050	$0.043	$0.036	$0.029
S19 Pro (110 TH/s | 29.5 J/TH)	$0.176	$0.169	$0.162	$0.155	$0.148	$0.141	$0.134	$0.127	$0.120	$0.113	$0.106	$0.099	$0.092	$0.085	$0.078	$0.071	$0.063	$0.056	$0.049	$0.042	$0.035	$0.028
S19j Pro (100 TH/s | 30.5 J/TH)	$0.171	$0.164	$0.157	$0.150	$0.143	$0.137	$0.130	$0.123	$0.116	$0.109	$0.102	$0.096	$0.089	$0.082	$0.075	$0.068	$0.061	$0.055	$0.048	$0.041	$0.034	$0.027
M30S+ (100 TH/s | 34 J/TH)	$0.153	$0.147	$0.141	$0.135	$0.129	$0.123	$0.116	$0.110	$0.104	$0.098	$0.092	$0.086	$0.080	$0.074	$0.067	$0.061	$0.055	$0.049	$0.043	$0.037	$0.031	$0.025
S19 (90 TH/s | 34.2 J/TH)	$0.152	$0.146	$0.140	$0.134	$0.128	$0.122	$0.116	$0.110	$0.104	$0.097	$0.091	$0.085	$0.079	$0.073	$0.067	$0.061	$0.055	$0.049	$0.043	$0.037	$0.030	$0.024
M30 (86 TH/s | 38 J/TH)	$0.137	$0.132	$0.126	$0.121	$0.115	$0.110	$0.104	$0.099	$0.093	$0.088	$0.082	$0.077	$0.071	$0.066	$0.060	$0.055	$0.049	$0.044	$0.038	$0.033	$0.027	$0.022
S17 Pro (56 TH/s | 45 J/TH)	$0.116	$0.111	$0.106	$0.102	$0.097	$0.093	$0.088	$0.083	$0.079	$0.074	$0.069	$0.065	$0.060	$0.056	$0.051	$0.046	$0.042	$0.037	$0.032	$0.028	$0.023	$0.019
M20 (68 TH/s | 49.4 J/TH)	$0.105	$0.101	$0.097	$0.093	$0.089	$0.084	$0.080	$0.076	$0.072	$0.067	$0.063	$0.059	$0.055	$0.051	$0.046	$0.042	$0.038	$0.034	$0.030	$0.025	$0.021	$0.017

Source: Hashrate Index

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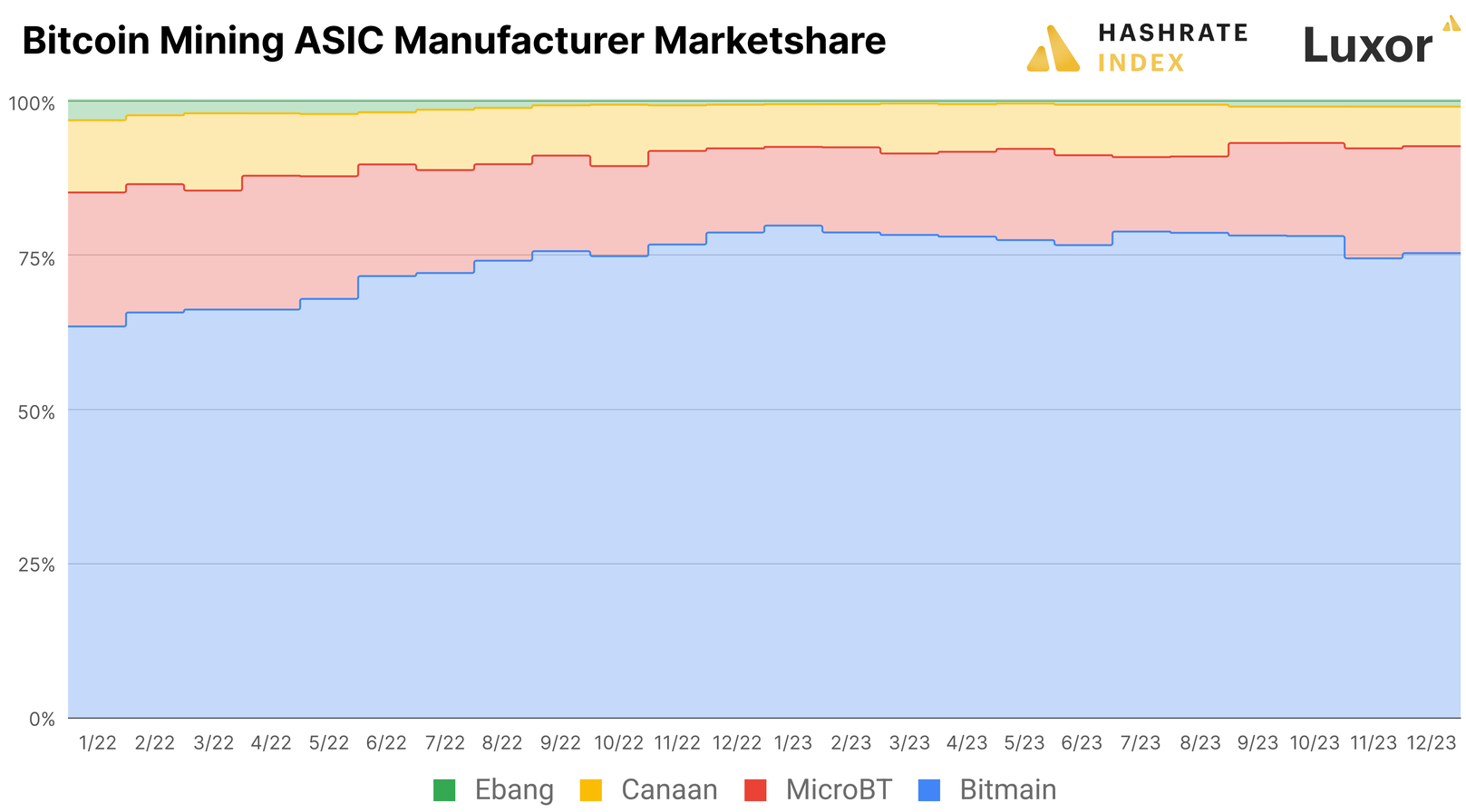
ASIC Market Share per Manufacturer and Model

During the current block subsidy epoch, four ASIC miner manufacturers have predominated: Bitmain, MicroBT, Canaan, and Ebang.

Bitmain and MicroBT take up the largest marketshare, while Canaan and Ebang have historically played a minor role. Using a nonce analysis scheme developed by Karim Helmy and published by Coin Metrics, we can now produce a roughly accurate view for just how much marketshare these manufacturers occupy. Nonce analysis examines the nonces produced by a sample of ASICs to sketch the rough makeup of the Bitcoin network by identifying the nonce patterns of individual miner models.

The chart below displays month-by-month estimates for hashrate produced by models from each ASIC miner manufacturer.

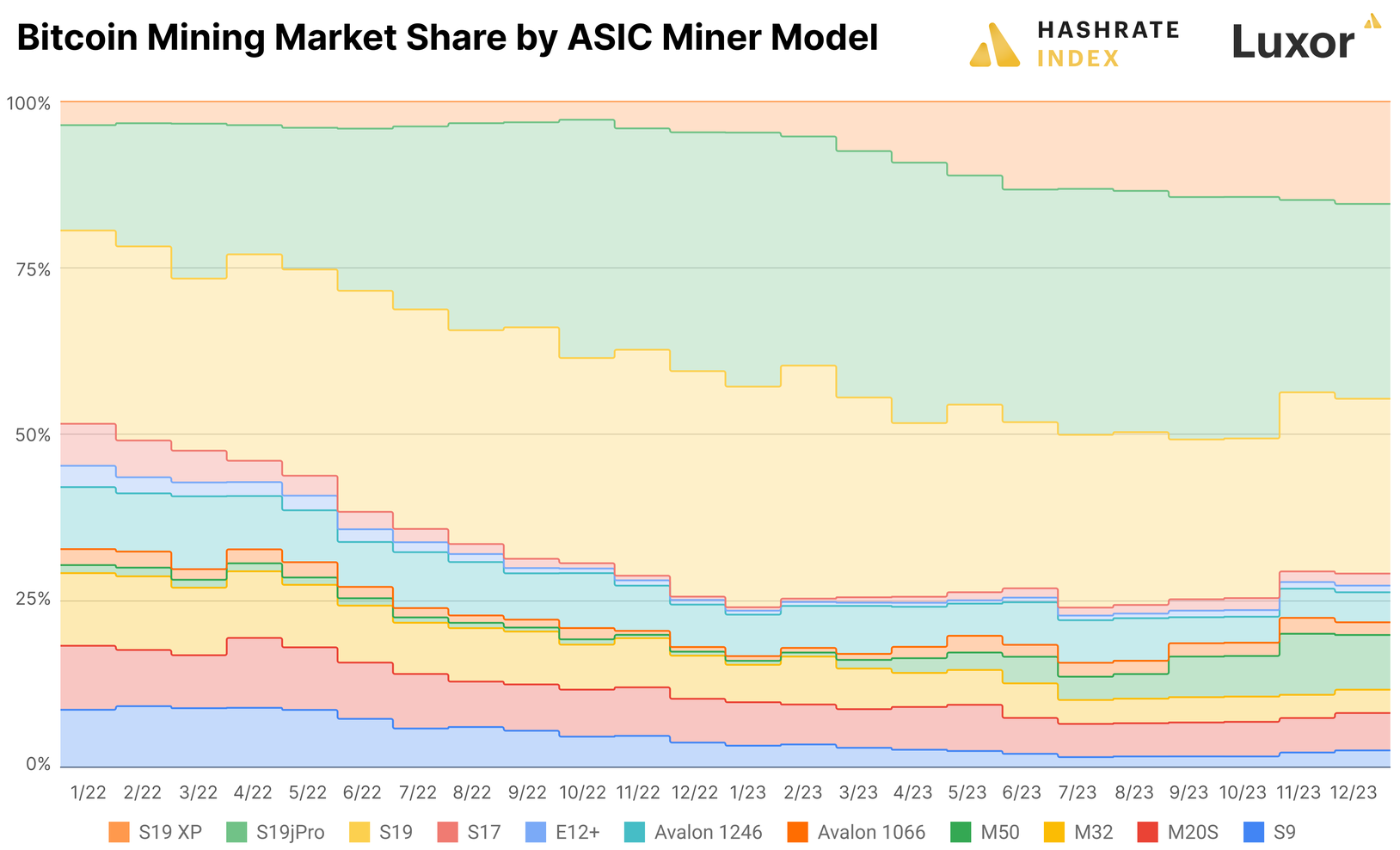


Source: Coin Metrics

According to this analysis, Bitmain's market share has increased 19% from January 2022 to December 2023 from 63.4% to 75.2%, but the top manufacturer's market share also declined over 2023 by 5%, falling from a peak of 79.5% in January 2023. Meanwhile, MicroBT lost ground from January 2022 to November 2023, with its market share falling 20% over this period from 21.7% to 17.3%; MicroBT entered 2023 with a market share of 12.7%, which increased by 36% over the course of the year.

The top two manufacturers in Bitmain and MicroBT continue to crowd out Canaan and Ebang, the latter of which saw their market shares decrease 45% and 69% respectively from January 2022 to November 2023; by November 2023, Canaan ASICs constituted 6.4% of the network while Ebang rigs barely made up 1%.

The chart below shows a model-by-model analysis. We can observe the gradual erosion of market share for older models like the S9, S17, and M20S throughout 2022 as the bear market became firmly entrenched. Conversely, as market conditions dramatically improved in Q4-2023 and hashprice perked up above $80/PH/day, miners recommissioned a portion of these older models to cash in on the action.

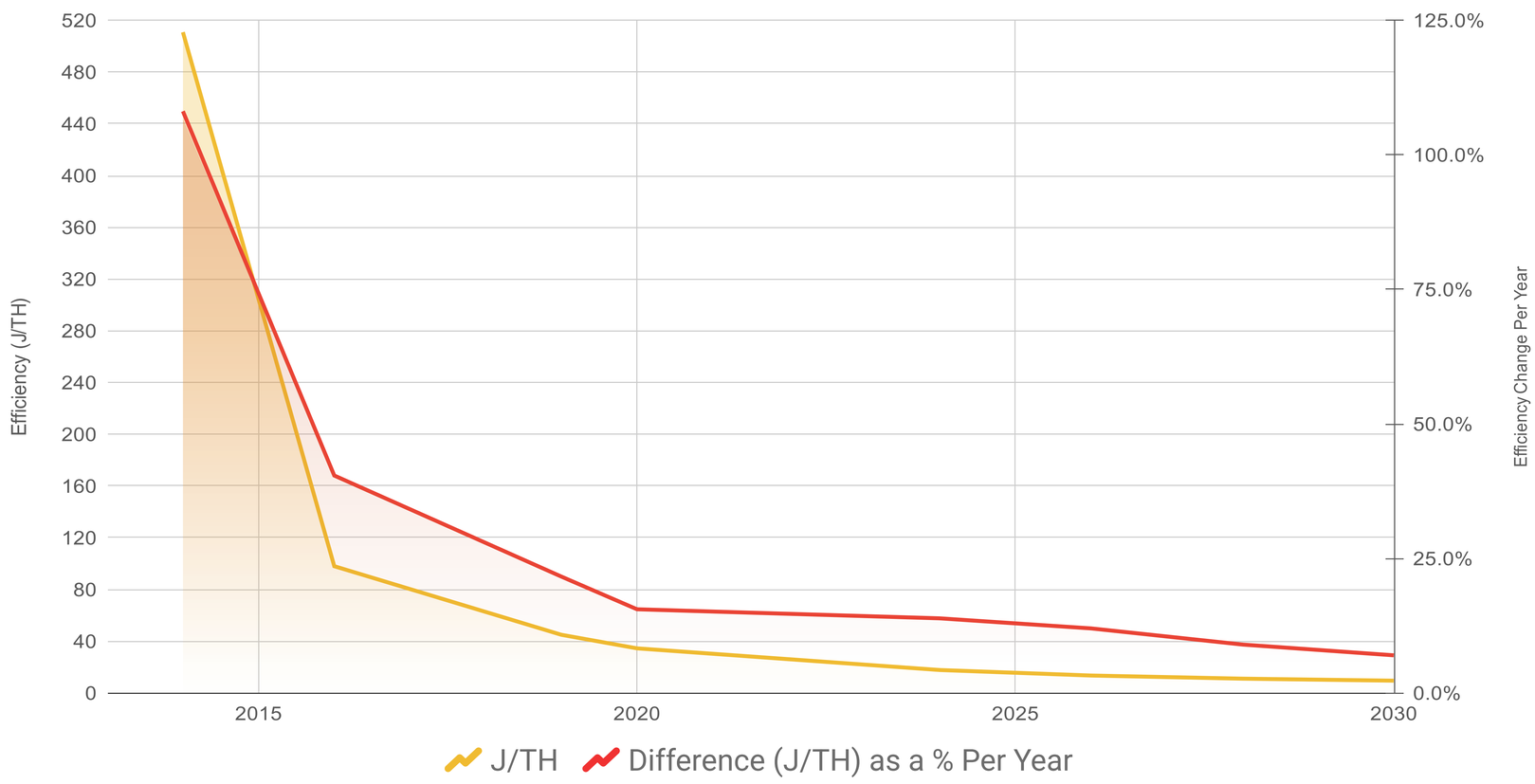


Source: Coin Metrics

Projecting Future Efficiency Gains

Since Bitmain's first ASIC miner, the S1, mining efficiency as measured by J/TH has improved significantly. While the efficiency increases are declining every year and loosely tracking Moore's law, each new model's efficiency gains are still significant for a miner's bottom line.

We estimate new generation machines to hit ~ 13 J/TH, 11 J/TH, and 9.5 J/TH over the next six years.



New Mining Rig Manufacturers Come to Market in 2023

A handful of new ASIC miner manufacturers came out of the woodwork in 2023, while other ASIC manufacturer hopefuls provided updates for their anticipated hardware. The introduction of new ASIC miner manufacturers offers the potential for greater diversity in a field currently dominated by Bitmain and MicroBT.

Auradine: Perhaps one of the most discussed of these new entrants, Auradine came on to the scene in May 2023 with $81 million under its belt from a series A, $35.5 million of which came from Marathon Digital. Specifications for Auradine's Teraflux mining rigs are hard to come by. That said, the company advertises that its flagship AT1500 can achieve up to 185 TH/s with overclocking, while its second model, the AT2880, can achieve 260 TH/s after overclocking; in Auradine's words, the "optimal" efficiency for either rig is 22 J/TH and 16 J/TH, respectively. These advertised specs would be industry leading if true, and as such, they have drawn scrutiny from many miners and analysts. It's hard enough to break into the ASIC miner manufacturing business (as Intel's ill-fated attempt in 2022 stands testament), so claiming to have industry-leading specifications out the gate is cause for healthy skepticism. That said, we're looking forward to seeing these models in action so that we can see what they're really capable of.

An Auradine AT1500 model | Source: Hashrate Index

Chain Reaction: Israel startup Chain Reaction, in partnership with publicly traded Bitcoin miner Bit Mining, announced its foray into ASIC miner manufacturing in May of 2023 after raising $70 million in February. There's limited information about their first ASIC, dubbed Electrum, but one press release advertises 140 TH/s at 19 J/TH.

DesiweMiner: Although DesiweMiner have been manufacturing ASIC miners since 2022, the company ramped up production in 2023 with the introduction of the K10 Ultra (advertised at 170 TH/s and 20.5 J/TH (+/- 5%)) and the K10 Pro (advertised at 170 TH/s and 22.5 J/TH (+/-5%)).

Blockstream: Bitcoin R&D firm Blockstream purchased ASIC miner manufacturer Spondoolies in 2022, and while they didn't release a rig in 2023, they beat the PR drum to herald the coming of their first ASIC miner offering at the earliest in Q3 of 2024.

Block: Jack Dorsey's Block announced in April of 2023 that the company is trying to break into the ASIC miner manufacturing business. Block kickstarted this effort by purchasing Intel's Blockscale ASIC chips. The company did not offer a concrete timeline for its first ASIC release, opting to only say that the flagship batch could come early in 2024.

ePIC: Canadian firm ePIC Blockchain released two mining rigs in 2023, the 520i at 112 TH/s and 33 J/TH and the 740a at 150 TH/s and 33 J/TH. ePIC leveraged Intel's Blockscale ASIC chips to outfit their rigs.

5

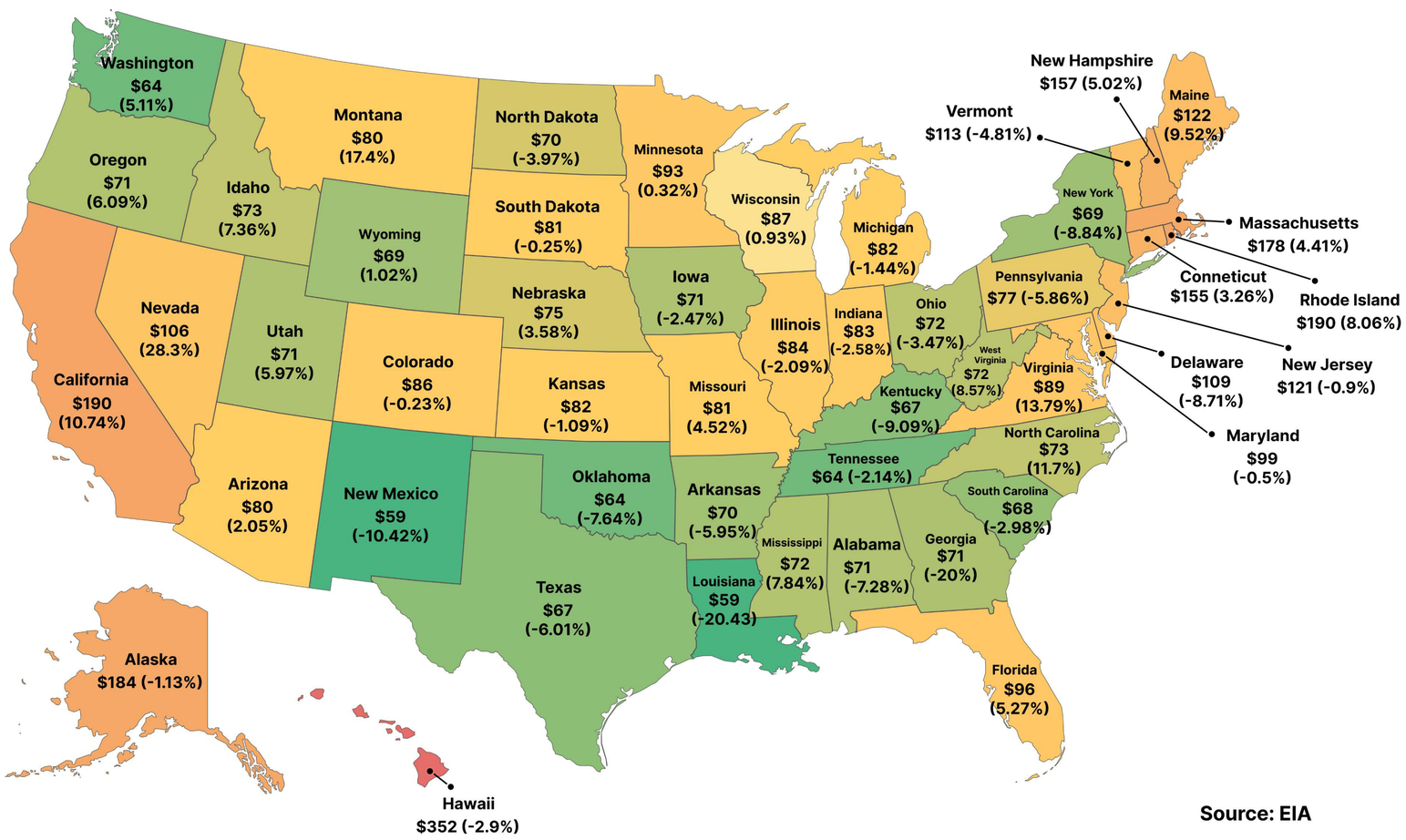
Energy Markets Stabilize

Power Prices Fall – But Only Slightly

In the US, electricity and fuel prices experienced record inflation in 2022. 2023 delivered some relief to this inflationary onslaught– but only slightly, and only to industrial power consumers.

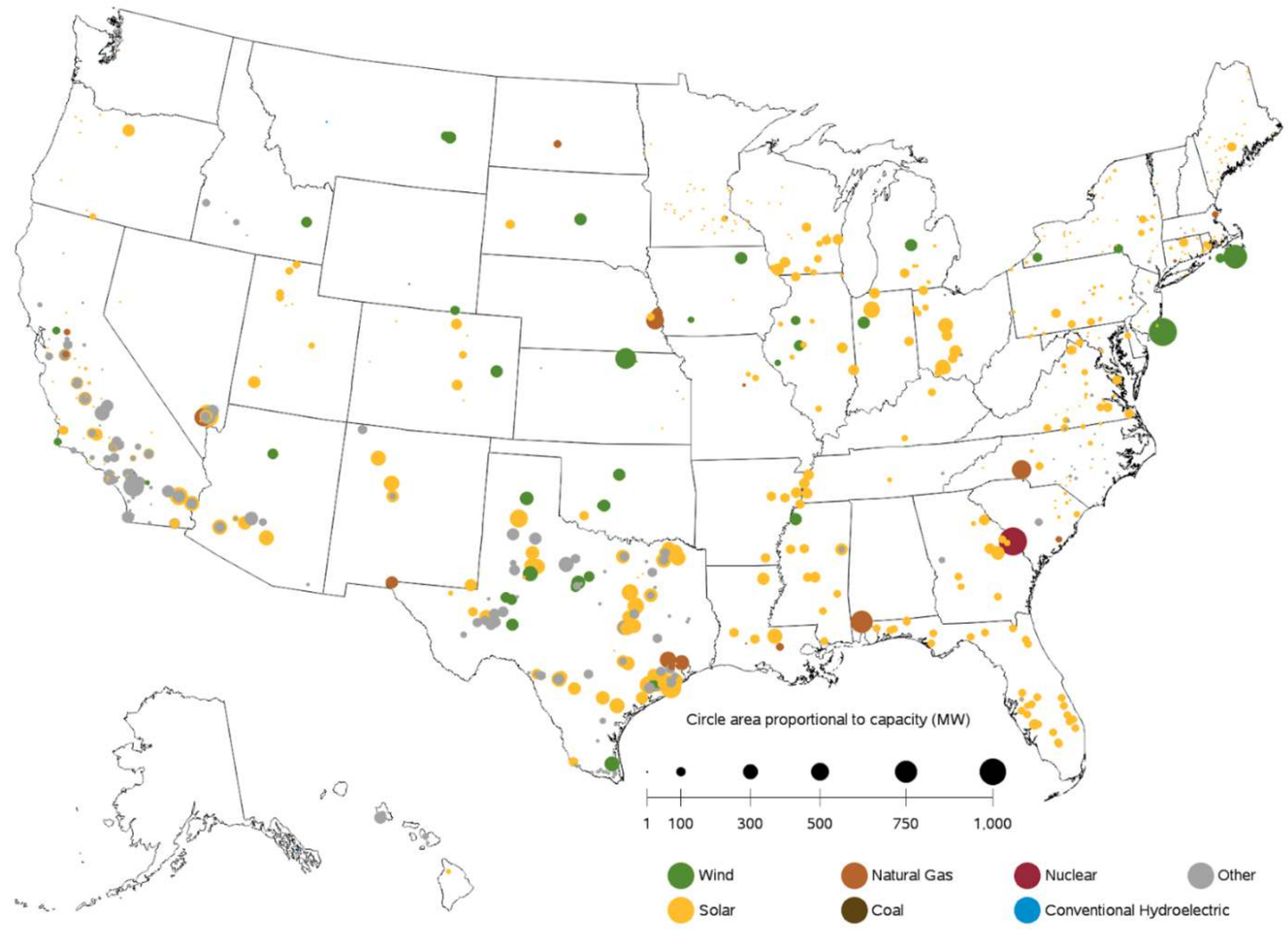
From January through October 2023 (the most up-to-date data), the average industrial price of electricity in the US was $81.3/MWh, a 2.3% decrease from $83.2/MWh during the same period in 2022. Over the same period, the average commercial electricity cost rose 3.1% from $128.1/MWh in 2022 to $124.3/MWh in 2023, and the average residential cost rose from $0.15/kWh in 2022 to $0.16/kWh in 2023.

Average Industrial Power Cost in $/MWh YTD Through October 2023 (With % Change from 2022)



As we've covered in previous reports, utility and power companies in the United States are overweighted toward renewable build outs. Per EIA data, solar and wind buildouts constitute the overwhelming majority of planned utility-scale generating assets over the next year. These wind and solar buildouts could be a benefit to certain renewables-focused Bitcoin miners who can make use of their intermittency, acting as on-site buyers of first and last resort. However, the expansion of the US's wind and solar capacity does not bode well for future power price inflation given their high variability and cost, especially considering the US is decommissioning baseload assets like natural gas, coal, and nuclear at a record pace.

Figure 6.1.C. Utility-Scale Generating Units Planned to Come Online from November 2023 to October 2024

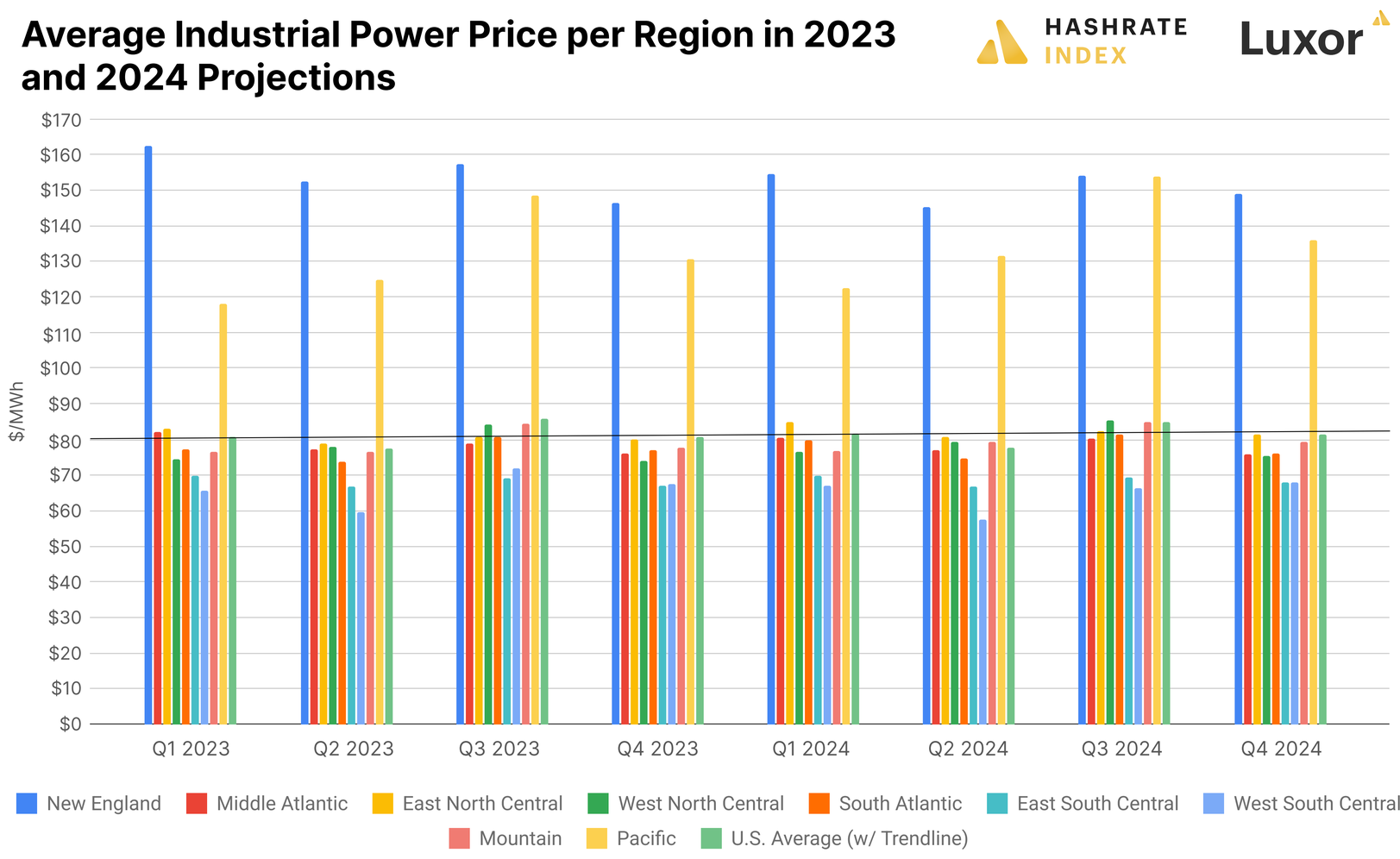


Sources: U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

Power Prices Likely to Rise in 2024

In the United States, projections indicate that 2024 could bring additional energy price inflation.

According to the EIA's projections, the average industrial power price in the US could change accordingly each quarter in 2024 from 2023's quarterly averages: +1.36% in Q1, +0.52% in Q2, -0.82% in Q3, and +1% in Q4. The chart below shows 2023's quarterly averages per region and 2024's quarterly projections, with the trendline reflecting the US average.



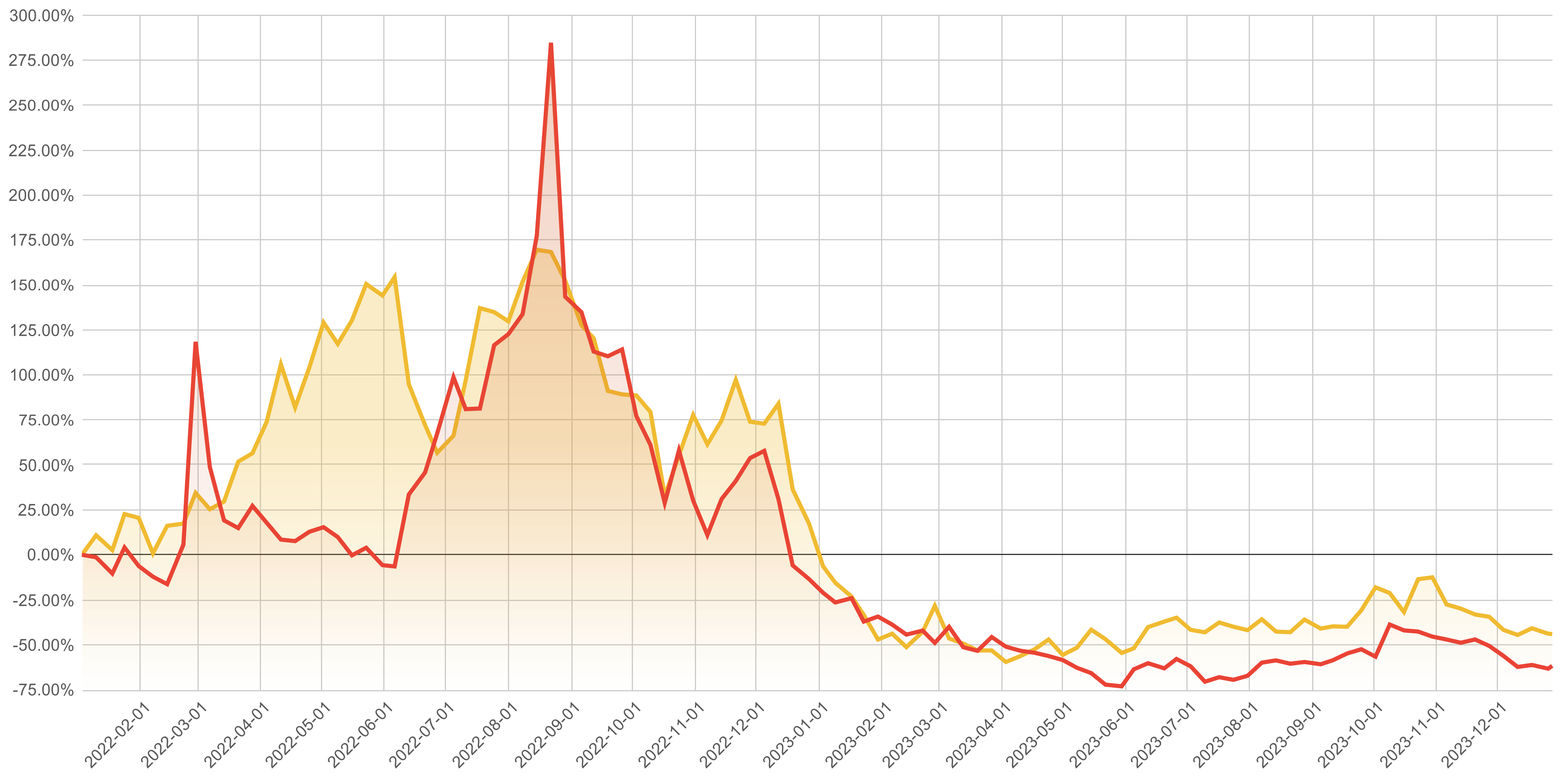
Source: EIA

Natural Gas Prices Come Down from 2022 Highs

Natural Gas prices fell significantly in 2023 after experiencing record price inflation in 2022.

From the market open in January 2022 to the market close in December 2023, Henry Hub futures (NG1!) fell 44%, while Dutch TTF futures (TTG1!) fell 62%. Zooming in on 2023, these futures fell 32% and 52%, respectively.

Henry Hub and Dutch TTF Futures Price Changes form January 3, 2022



Source: Trading View

For 2024, the EIA is forecasting an average natural gas price of $2.9/MMBtu in the US, a 15% increase from 2023's $2.53/MMBtu average, a 57% decrease from 2022's average of $6.67/MMBtu, a 29% decrease from 2021's average of $4.06/MMBtu, and a 37% increase from 2020's average of $2.11/MMBtu.

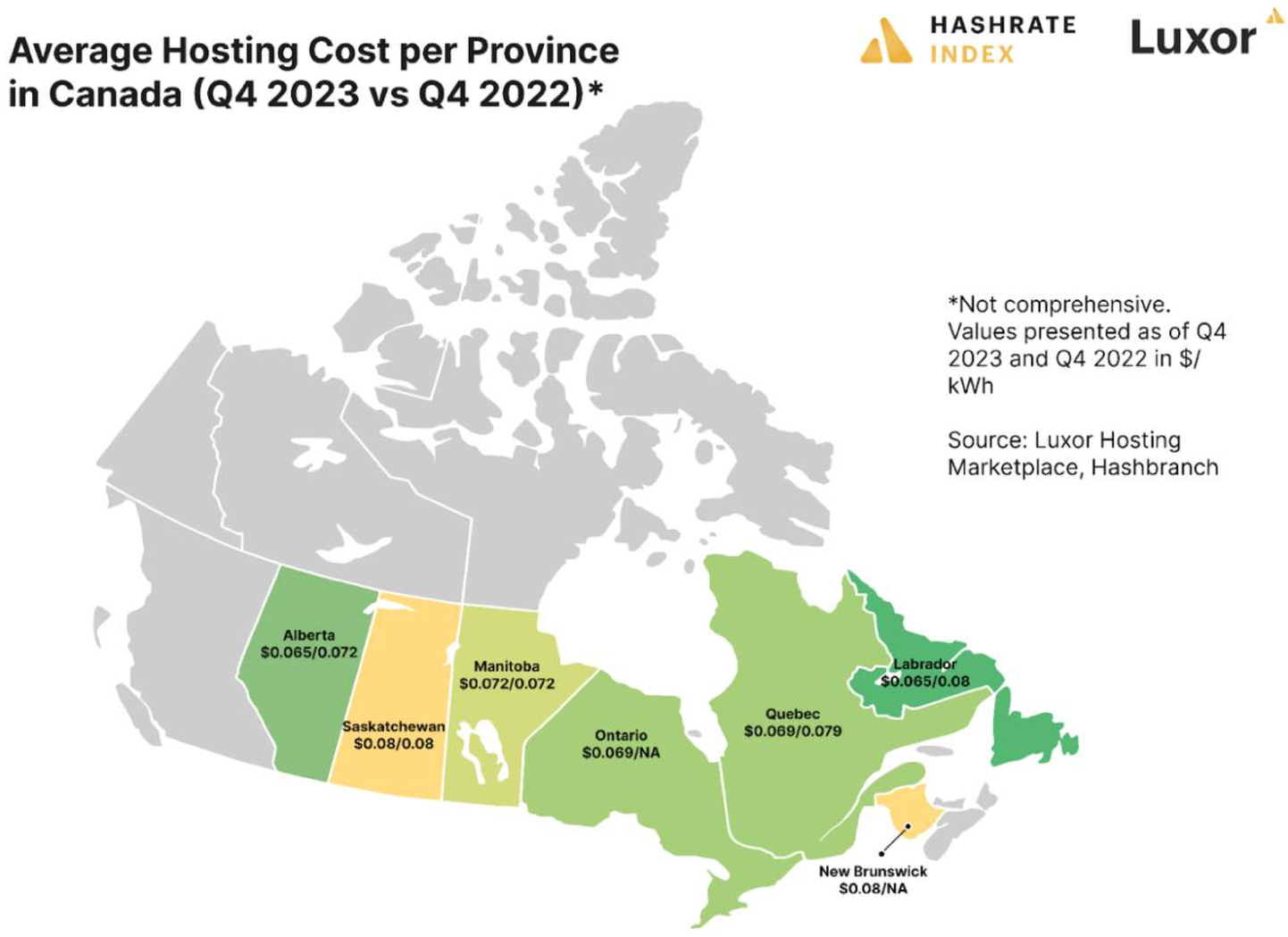
According to the EIA, natural gas inventories in the US are above their 5 year average, a trend the agency anticipates will stick as we progress through winter in 2024. These reserves are the result of a record-breaking year for domestic oil and gas production in the US.

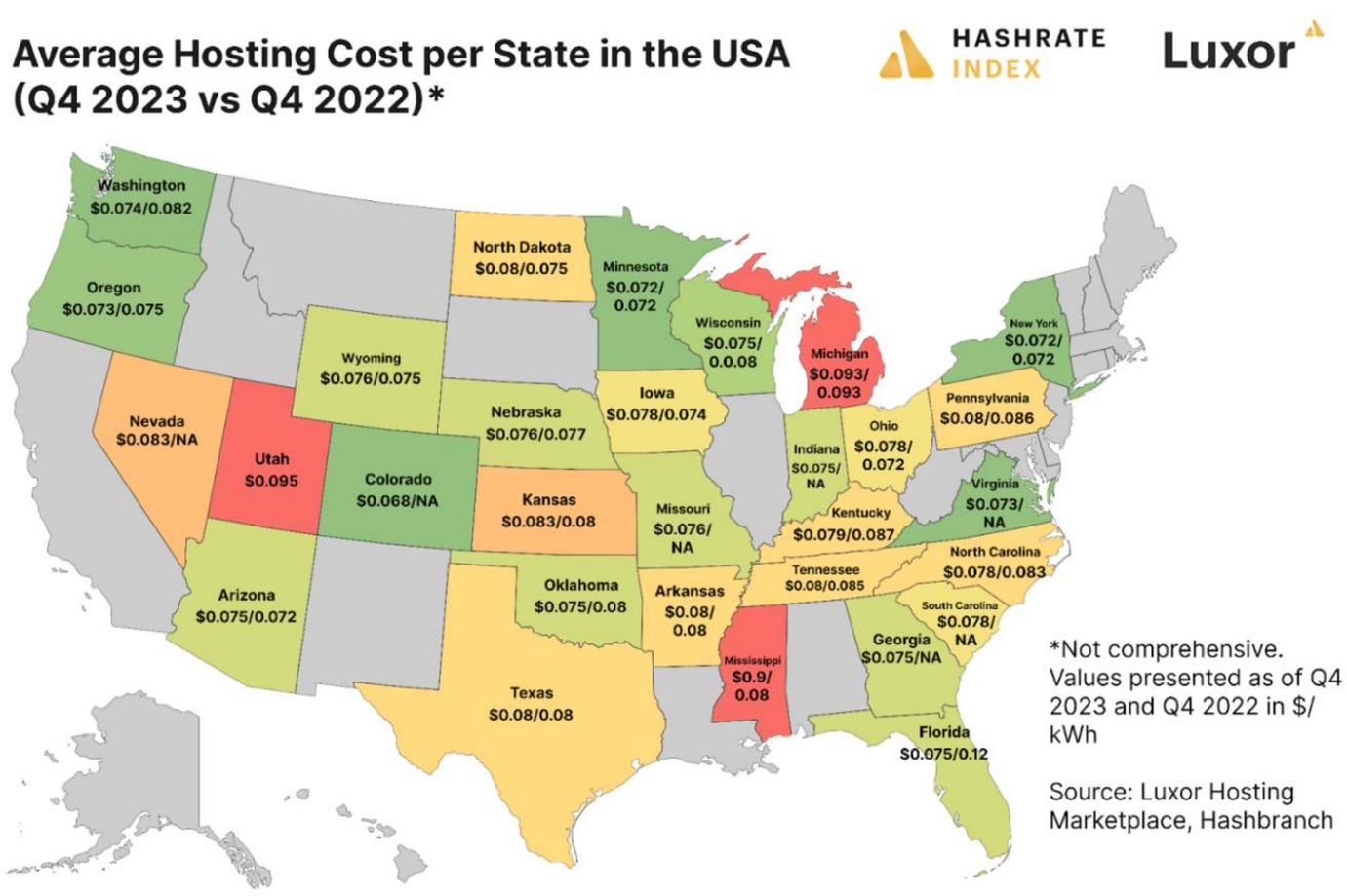
6

Hosting Data

In aggregate, Bitcoin mining hosting rates fell over the course of 2023.

While there is no one-size-fits-all approach to Bitcoin mining hosting, rates typically move up or down according to energy markets. Indeed, we saw hosting rates balloon in 2022 as energy and electricity prices inflated, so much so that the average all-in hosting rate according to our hosting index reached $0.082/kWh in Q4-2022; with hahsprice trading in a range between $55-62/PH/day at the time, this average hosting rate would have rendered many miners unprofitable unless they had next-generation equipment.





Fast forward to 2023, and the average all-in hosting rate for the year was $0.078/kWh in the US and $0.072/kWh in Canada; in Q4-2023, the average all-in rate was $0.078/kWh and $0.071/kWh, respectively. While not a drastic change, the drop in hosting rates gave the average miner a bit more operational breathing room and allowed them to pocket more margin from 2023's impressive hashprice rally. Given the impact that the Fourth Halving will have on mining revenues, we're anticipating a serious shakeup of the Bitcoin mining hosting industry in the US and Canada this year, particularly for small-to-midsize, retail focused hosting companies.

If bitcoin doubles (or more) in price over 2024, then this shakeup may be avoided in the short term, but otherwise, it's going to be difficult for many hosting companies to retain clients after the Halving reduces mining revenues by 50% and these clients likely drop below profitability thresholds.

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7

Bitcoin Mining Stocks Make a Comeback

As the public Bitcoin mining market has matured, public Bitcoin miners have grown their operational footprints beyond their historic bases of operation in the US and Canada. As of 2023, the majort public miners collectively operate across 4 continents. We anticipated that geographic distribution will continue to be a major trend for public miners in the years following the Fourth Halving.

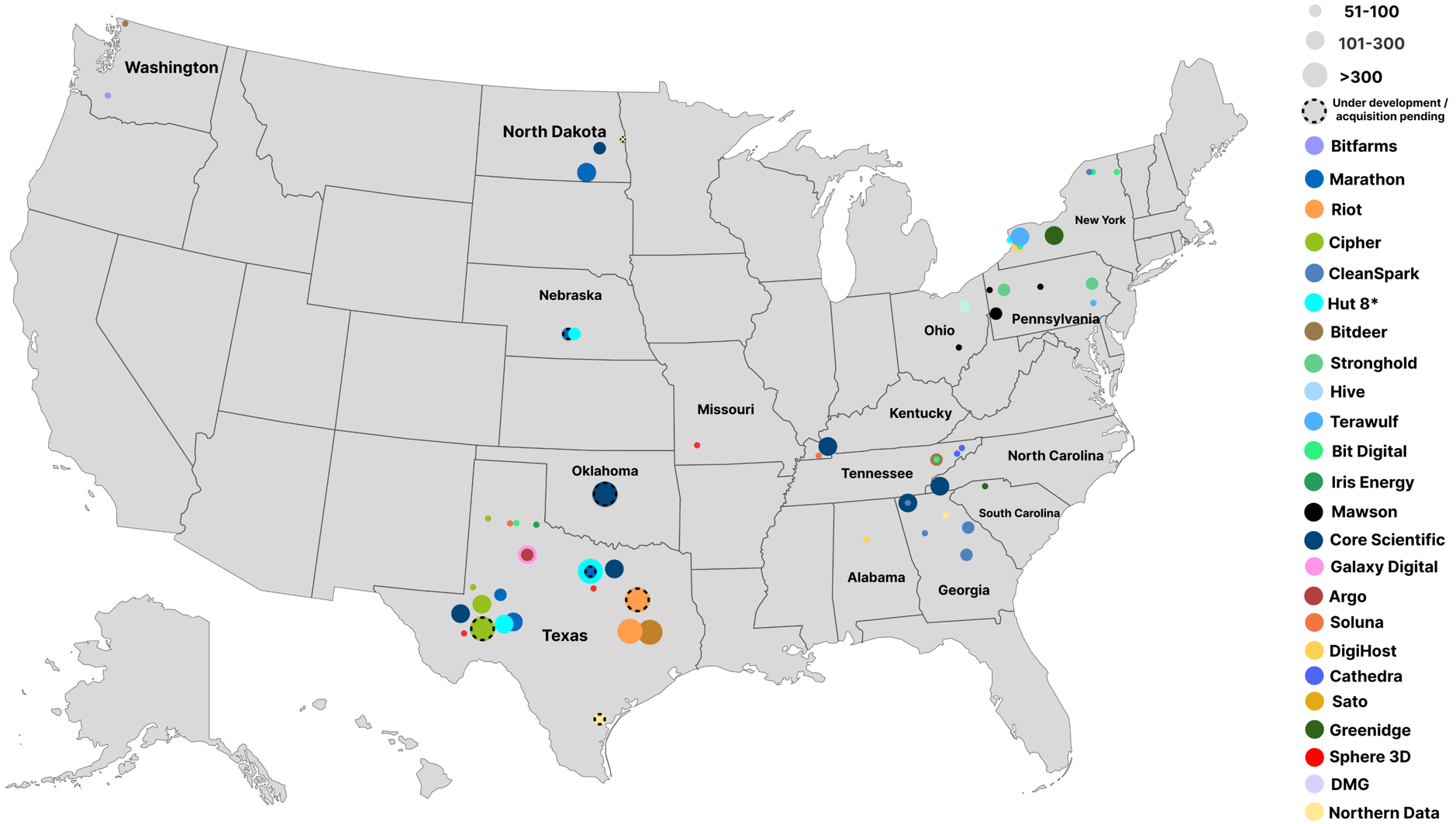
Public Bitcoin Miner Operations

HASHRATE INDEX Luxor

Source: Public disclosures

Public Bitcoin Miner Operations

HASHRATE INDEX Luxor



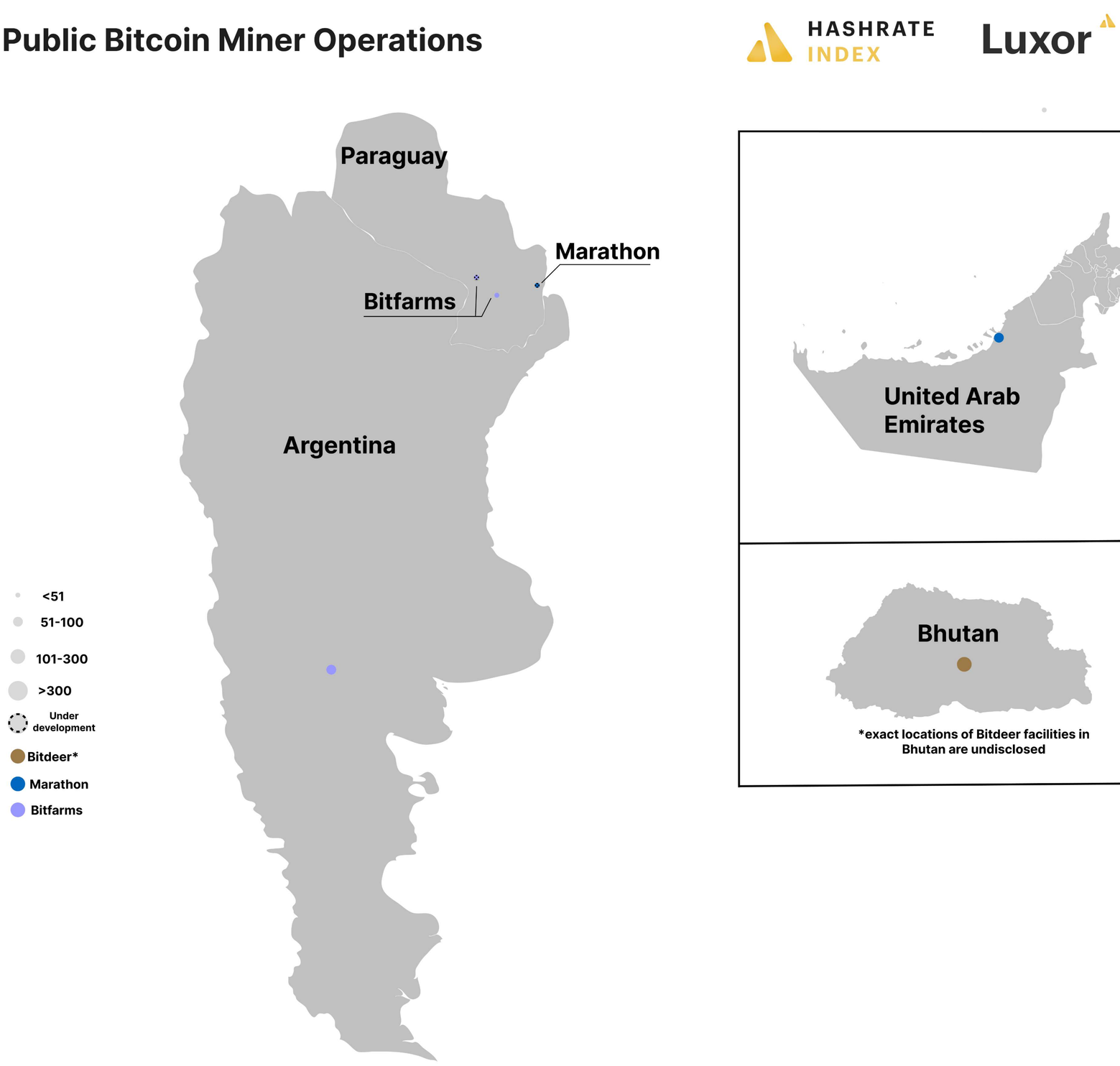
Source: Public disclosures

*Also includes managed (but not owned) sites

Public Bitcoin Miner Operations

Source: Public disclosures

Public Bitcoin Miner Operations

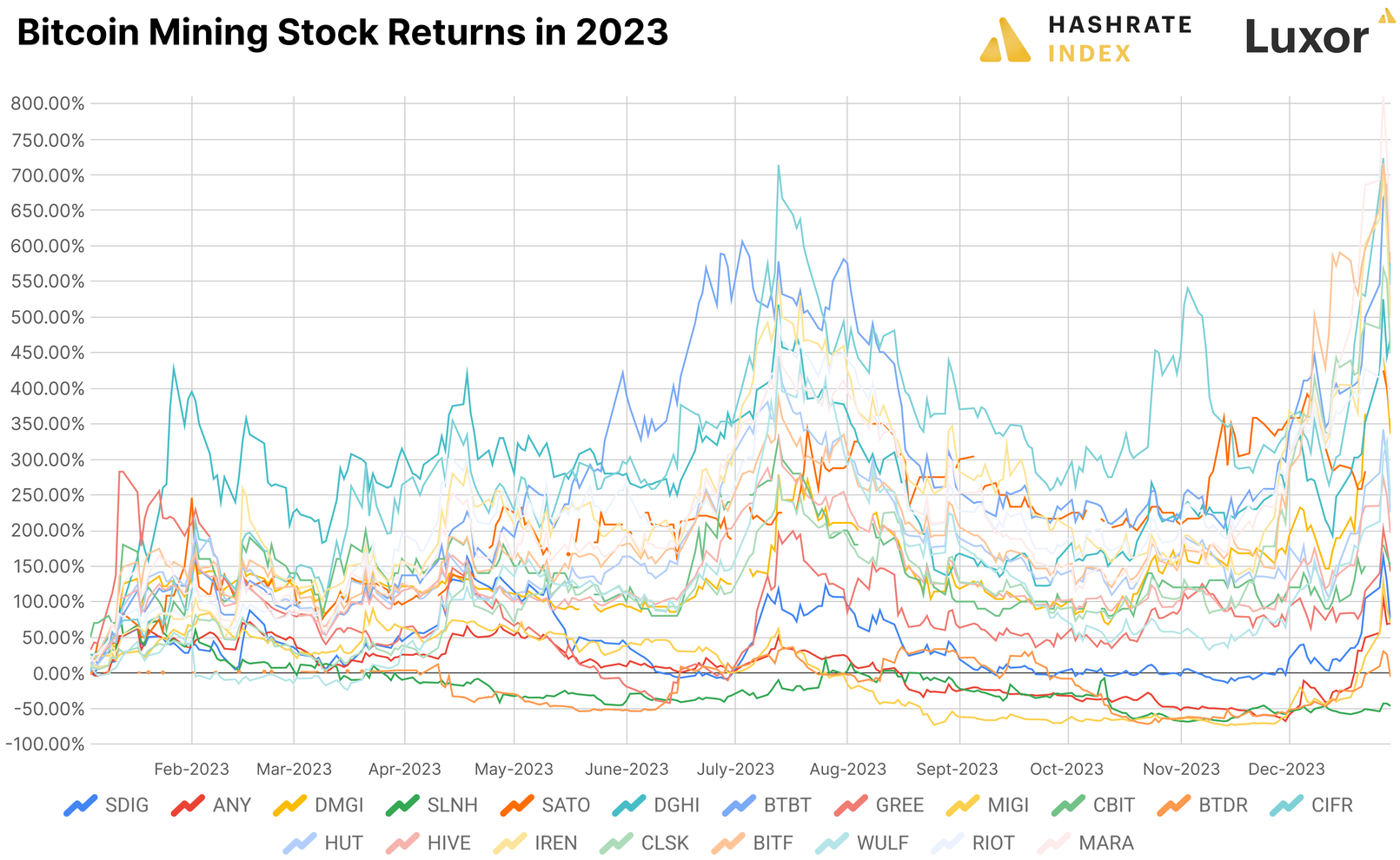


Source: Public disclosures

2023 was a comeback year for Bitcoin and its mining industry, and Bitcoin mining stocks were certainly no exception to the revival.

Investors treat Bitcoin mining stocks as high-beta vehicles for Bitcoin exposure, so with Bitcoin and hashprice rebounding, Bitcoin mining stocks rebounded even harder. **Many stocks saw triple digit returns over the course of 2023, with the top 5 gainers being Marathon (591%), Bitfarms (582%), Bit Digital (553%), Cipher (546%), and Iris Energy (501%).** The only notable Bitcoin mining stocks that closed in the red last year were Bitdeer and Soluna Holdings, the former of which went public on the Nasdaq Exchange last April.

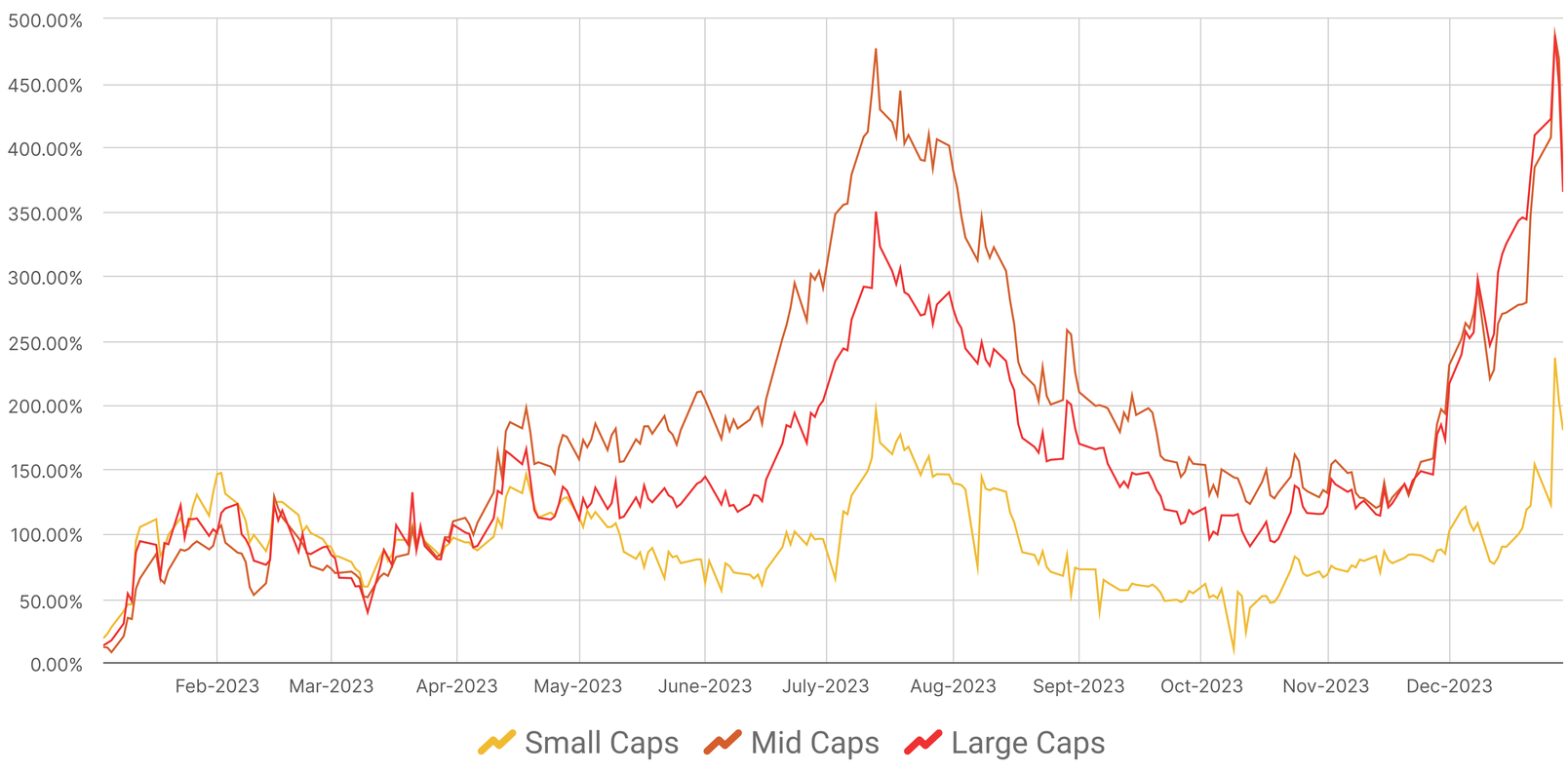
Bitcoin Mining Stock Returns in 2023



Source: Trading View

Generally speaking, bigger miners had larger rates of return. The chart below shows the average rate of return for publicly traded Bitcoin miners over the course of 2023. We break up the miners into buckets according to their market capitalizations at the end of 2023, where small cap miners are those with capitalizations under $200 million, mid cap miners are those with capitalizations between $200 million and $1 billion, and large cap miners are those with capitalizations greater than $1 billion.

2023 Average Price Performance of Small, Mid, and Large Cap Bitcoin Mining Stocks



Source: Trading View

Interestingly, the mid cap group had the greatest rate of return in 2023, although they beat out large cap miners only slightly; mid cap miners also saw the largest return by the middle of the year by a wide margin. This could be attributed to the fact that these miners were oversold at the end of 2022 compared to large cap miners, the latter of which generally have greater liquidity and are more ubiquitous across different markets and indices. Inversely, small cap miners, which have the least liquidity of the bunch, offered the lowest return in 2023.

Public Bitcoin Miner Financial and Valuation Data

As a result of the superb share price increases almost every public miner enjoyed in 2023, these companies were much more healthy financially at the end of 2023 than 2022.

2023 Financials* (% Change from 2022)	Enterprise Value	Market Cap	Share Price	EV/Sales	EV/Hashrate
Riot	$2,648m (+1,095%)	$3,284m (+479%)	$15.89 (+369%)	10.1 (+1,082%)	214 (+835%)
Marathon	$5,138m (+486%)	$5,813m (+1,355%)	$25.99 (+660%)	34.3 (+362%)	208 (+66%)
Hut 8	$650m (+4,795%)	$1,060m (+533%)	$11.90 (+180%)	8.8 (+5,342%)	90 (+1,600%)
Bitfarms	$647m (+551%)	$721m (+704%)	$2.98 (+577%)	5.1 (+629%)	99 (+351%)
Cleanspark	$1,843m (+1,037%)	$1,997m (+1,265%)	$10.73 (+426%)	10.9 (+1,027%)	183 (+599%)
Hive	$316m (+223%)	$377m (+219%)	$4.30 (+199%)	1.9 (+105%)	77 (+66%)
Stronghold	$139m (-29%)	$85m (-37%)	$7.60 (+59%)	1.8 (-2%)	40 (-43%)
Cipher	$959m (+696%)	$1,000m (+621%)	$3.91 (+598%)	11.1 (-72%)	133 (+210%)
Bitdeer	$837m (+128%)	$968m (+66%)	$8.66 (-17%)	2.5 (+129%)	100 (+11%)
Core Scientific	$1,394m (+102%)	$650m (+2,211%)	$1.70 (+2,164%)	2.6 (+143%)	82 (+87%)
Terawulf	$609m (+181%)	$491m (+498%)	$2.06 (+209%)	11 (-24%)	122 (-21%)
Iris	$354m (1,738%)	$423m (+515%)	$6.17 (+394%)	4.7 (+1,738%)	63 (+392%)

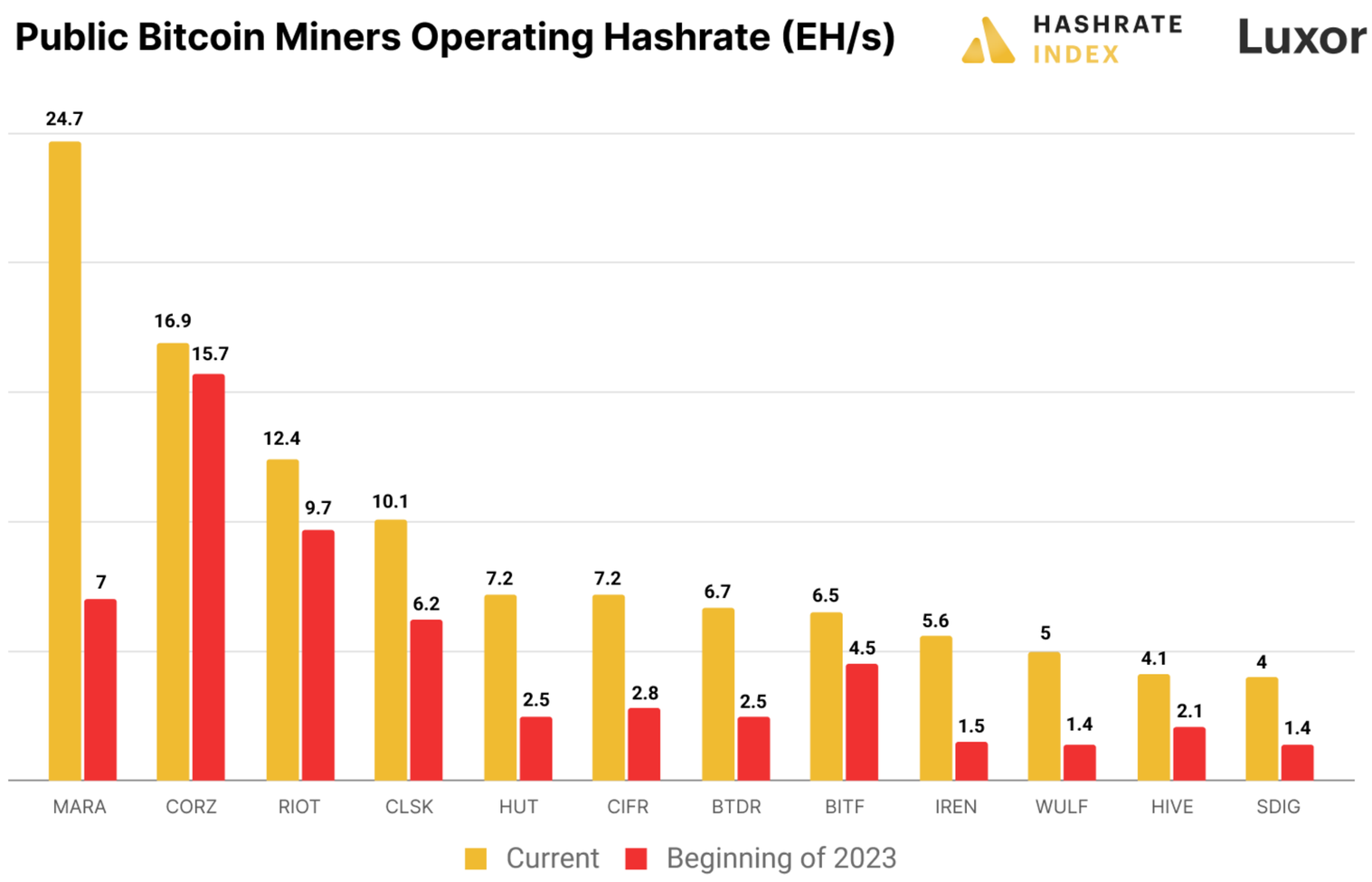
*EV, Sales based on Q3-2023 reported data | **Trailing 12-month revenue | Source: Most Recent Financial Statements, Tradingview

With the exception of only a couple of miners, every public Bitcoin miner saw incredible increases to both their market caps and enterprise values over 2023. Additionally, the increase in share prices allowed them to take advantage of equity sales to fundraise, and they spent this cash on reducing debt and/or expanding their operations (more details on this in the financing/fundraising section and expansion section).

The public miners' share price increases are reflected in their rising valuation metrics. As you can see in the table, most companies have seen their EV/Sales and EV/Hashrate ratios surge by several hundred percentage points, taking their valuations out of the depressed territory into a more normal range. Currently, the median EV/Sales ratio among the 12 companies we track is 7, which is more than double the average of the S&P 500, which is 2.6. However, as you can see, there are massive valuation discrepancies among these companies, giving great opportunities for value investors to find undervalued gems.

Public Bitcoin Miner Financial and Valuation Data

2023 was a year of great expansion for most public miners. Of the 12 miners we track, 7 of them more than doubled their hashrate over the year. Marathon saw the most growth, expanding its hashrate from 7 EH/s to 24.7 EH/s.



Source: Monthly production updates

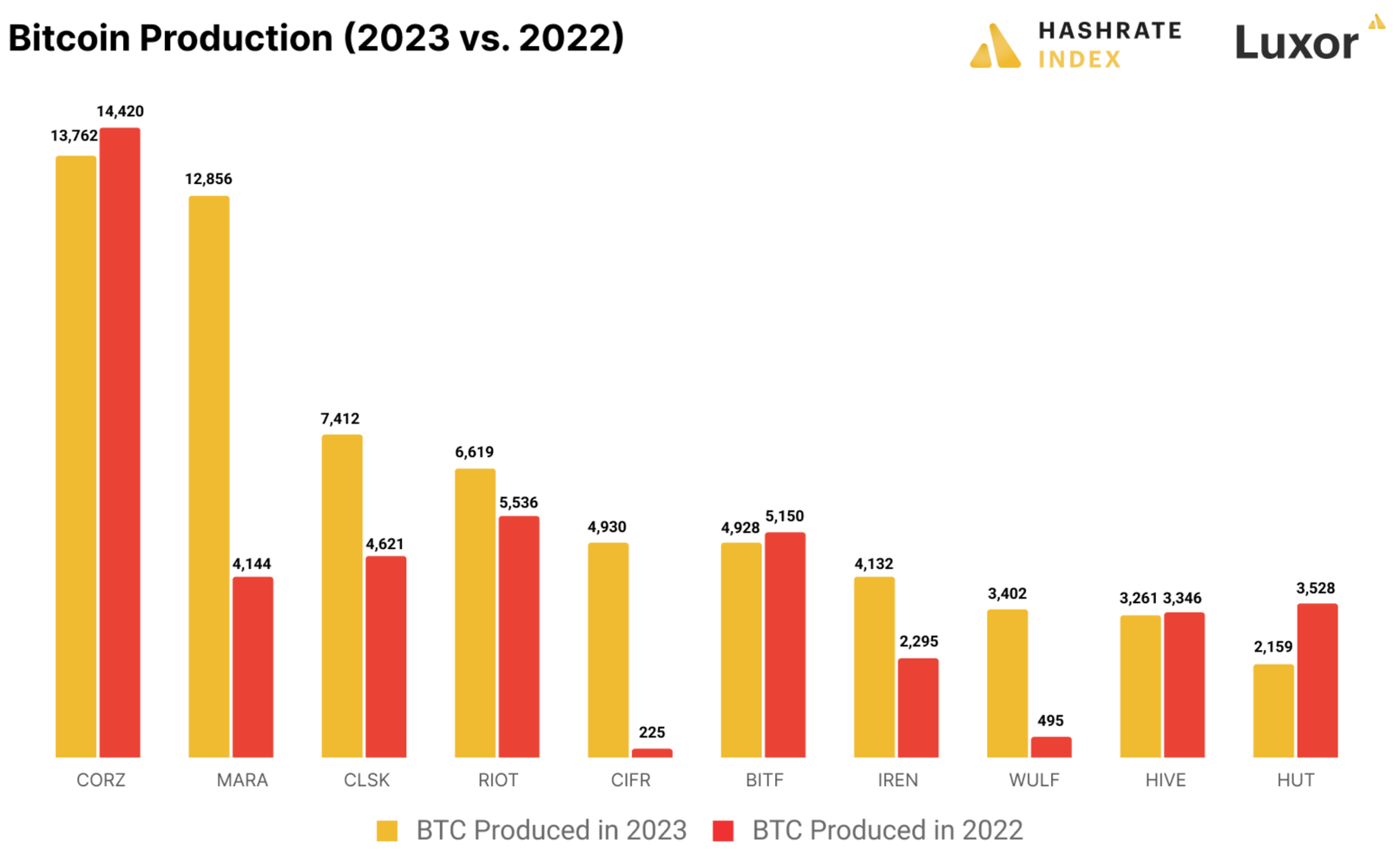
In total, the public miners now control around 125 EH/s of self-mining capacity, which is double the 62 EH/s they wielded at the start of 2023. **At the same time, private miners (which we measure by looking at total Bitcoin network hashrate) have grown quicker, meaning the public miners' share of the network declined from 34% to 24% over 2023.** This signals that a large part of the hashrate growth in 2023 has not come from the United States or Canada but from other parts of the world. Public miners had increasingly gained market share in 2021 and 2022, but that trend has now reversed.

Still, the clear trend with operating hashrate in 2023 was increased capacity and growth among all of the publicly traded miners. With network hashrate steadily moving higher in 2023, miners had no choice but to expand and grow fleet efficiency to remain competitive. Many new facilities came online, increasing capacity for Marathon, Bitfarms, Terawulf, Cipher Mining, Iris Energy, Stronghold, and Bitdeer. Other miners expanded through acquisitions, including Cleanspark and Hut 8. Core Scientific and Hive were able to increase their hashrate through incremental fleet upgrades within their existing facilities.

Some of the largest gains in mined bitcoin for certain Bitcoin mining companies came from large expansions in new mining centers. Marathon saw significant growth, as the company fully energized its Garden City and North Dakota mining facilities. Terawulf and Cipher Mining increased production significantly in 2023 after they finally energized their new data centers in 2023. Hut 8 showed declines in mined Bitcoin as their North Bay facility was offline due to disputes with power providers, and their Drumheller facility suffered voltage issues with miner firmware.

Going into 2024, we expect to see significant efficiency gains in new mining equipment along with more power capacity coming online for Iris Energy, Hut 8, Bitfarms, Riot, and Core Scientific. Marathon, Hive, and Cleanspark will likely expand mining capacity through acquisitions and partnerships (Marathon, for instance, is in the process of acquiring two facilities from Generate Capital, the Kearney, NB and Granbury, TX sites that Generate acquired from Compute North's bankruptcy in 2022).

As we highlight later in this chapter, the public miners have recently made massive ASIC orders that will be delivered in 2024, meaning the public miner share of the global hashrate could start increasing again. We predict it will be between 25% and 30% by the end of 2024.



Source: Monthly production updates

With expansion comes greater bitcoin production capabilities. Some of the public miners grew their bitcoin production massively over the year, with Marathon achieving the most growth from 4,144 BTC in 2022 to a massive 12,856 BTC in 2023. With these solid numbers, Marathon produced the second-most bitcoin of the public miners, only beat by Core Scientific with 13,762 BTC. However, due to its recent hashrate surge, Marathon is now producing the most on a daily basis, demonstrated by its pool securing 5.1% of the network's block rewards in December 2023.

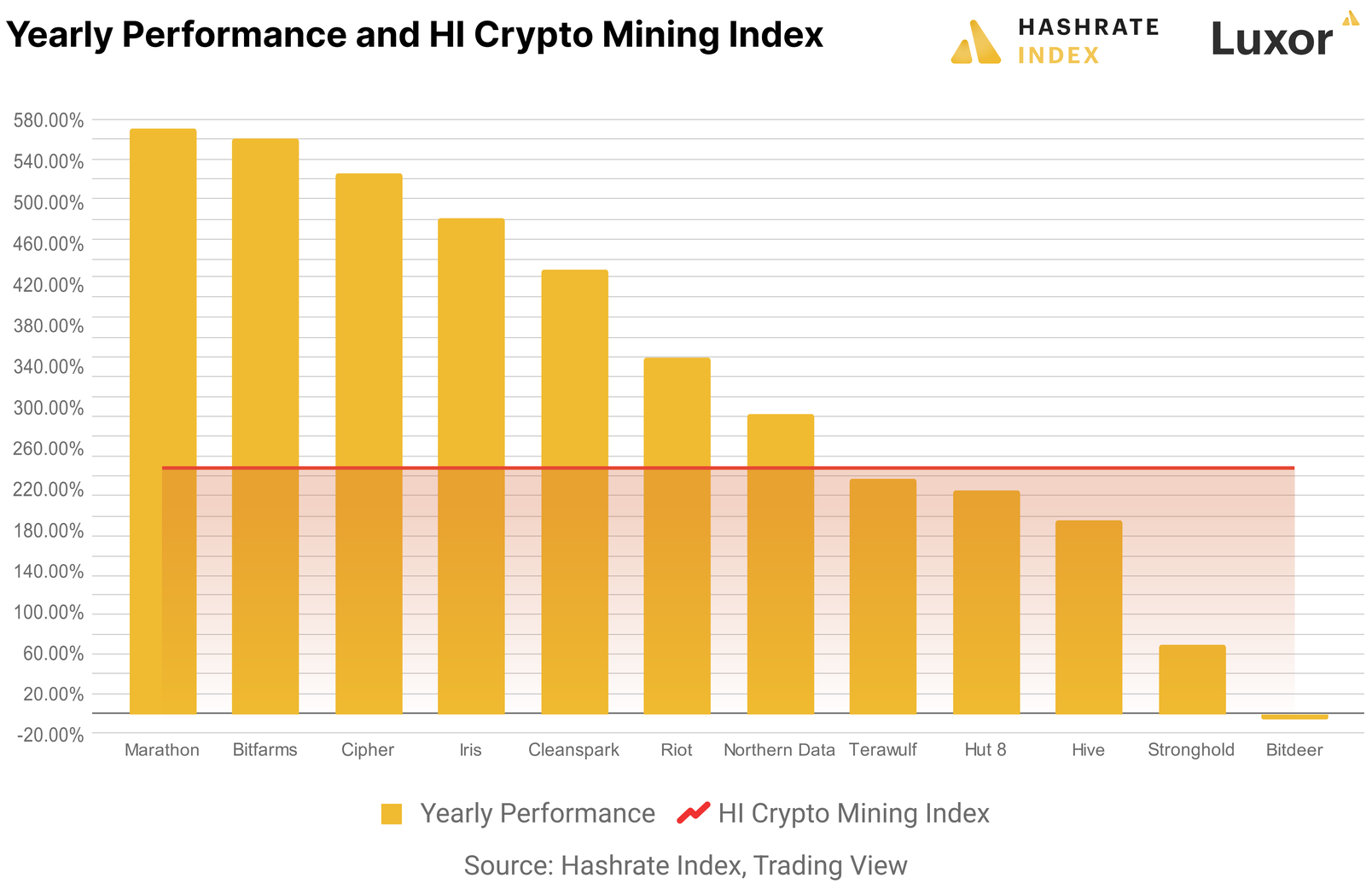
Other companies with massive bitcoin production growth in 2024 include CleanSpark, Cipher, Iris Energy, and Terawulf. Notably, Cipher and Terawulf both had their first full year of operations, thus growing their production tremendously. CleanSpark and Iris Energy saw more organic growth, as they continued expanding their existing large-scale operations.

Surprisingly, Core Scientific, Bitfarms, Hive, and Hut 8 all saw negative growth in their bitcoin production in 2023 as they didn't keep up with the massive network hashrate increase. However, all these companies, except for Core Scientific, are heavily expanding operations and will likely see substantial bitcoin production increases in 2024, if we don't account for the halving.

Overall, the public miners are preparing for continuous growth in 2024, which they view as incredibly important in order to keep bitcoin flowing into their coffers in the post-halving environment.

Hashrate Index Crypto Mining Index, Stock Correlations, and Public Miner Groupings

Hashrate Index's Crypto Mining Stock Index tracks over 60 mining companies that are traded on major exchanges and OTC, with weightings based on their market-caps. Using this data we can benchmark stock price performance relative to the average of these companies. In 2023, most of the large-cap companies outperformed the index (which includes mid and small cap miners), however there were a few that underperformed the market (like Bitdeer, for example, whose performance was likely hampered by the fact that the company just IPO'd in 2023).



Source: Hashrate Index, Trading View

Public mining stocks have a very strong correlation to not only the price of Bitcoin but also each other. The companies with the highest correlation to each other are the largest cap mining stocks.

Correlations	Riot	Marathon	Hive	Cleanspark	Iris	Hut 8	Bitfarms	Stronghold	ND	Cipher	Bitdeer	Terawulf	Core Sci	Bitcoin
Riot	1.0													
Marathon	0.9	1.0												
Hive	0.8	0.8	1.0											
Cleanspark	0.8	0.9	0.6	1.0										
Iris	0.9	0.9	0.9	0.8	1.0									
Hut 8	0.8	0.8	0.9	0.5	0.8	1.0								
Bitfarms	0.8	0.9	0.7	1.0	0.8	0.6	1.0							
Stronghold	0.4	0.4	0.5	0.2	0.4	0.3	0.3	1.0						
Northern Data	0.7	0.5	0.4	0.6	0.6	0.4	0.5	-0.1	1.0					
Cipher	0.9	0.8	0.8	0.7	0.8	0.8	0.7	0.2	0.7	1.0				
Bitdeer	0.0	0.2	0.4	0.0	0.2	0.3	0.1	0.2	-0.4	0.0	1.0			
Terawulf	0.9	0.8	0.9	0.6	0.9	0.9	0.6	0.5	0.4	0.8	0.3	1.0		
Core Sci	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.2	0.7	0.9	0.2	0.7	1.0	
Bitcoin	0.7	0.7	0.4	0.8	0.6	0.3	0.7	0.0	0.8	0.6	-0.4	0.3	0.6	1.0

Source: Hashrate Index, Trading View

Although miners are constantly changing strategies, you can group them based on exchange listing, vertical integration, and area of focus.

2023E Market Cap By Exchange	
Nasdaq	
Riot	3.28B
Marathon	5.81B
Hive	377M
Cleanspark	2.00B
Iris	423M
Hut 8	1.06B
Bitfarms	721M
Stronghold	85M
Cipher	1.00B
Bitdeer	968M
Terawulf	491M
TSX	
Hut 8	1.414B
Bitfarms	1.173B
XETRA	
Northern Data	1.19B
OTC	
Core Sci	650M

2023E Market Cap By Vertical Integration	
Asset Light	
Marathon	5.81B
Own Land and Building	
Riot	3.28B
Hive	377M
Cleanspark	2.00B
Iris	423M
Hut 8	1.06B
Bitfarms	721M
Northern Data	1.19B
Bitdeer	968M
Core Sci	650M
Own Power-Plant (or JV)	
Stronghold	85M
Cipher	1.00B
Terawulf	491M

2023E Market Cap By Area of Focus	
Bitcoin Mining Only	
Marathon	5.81B
Cleanspark	2.00B
Iris	423M
Bitfarms	721M
Cipher	1.00B
Bitdeer	968M
Terawulf	491M
Core Sci	650M
Bitcoin Mining and Energy	
Riot	3.28B
Stronghold	85M
Bitcoin Mining and High-Performance Compute	
Hive	377M
Hut 8	1.06B
Northern Data	1.19B

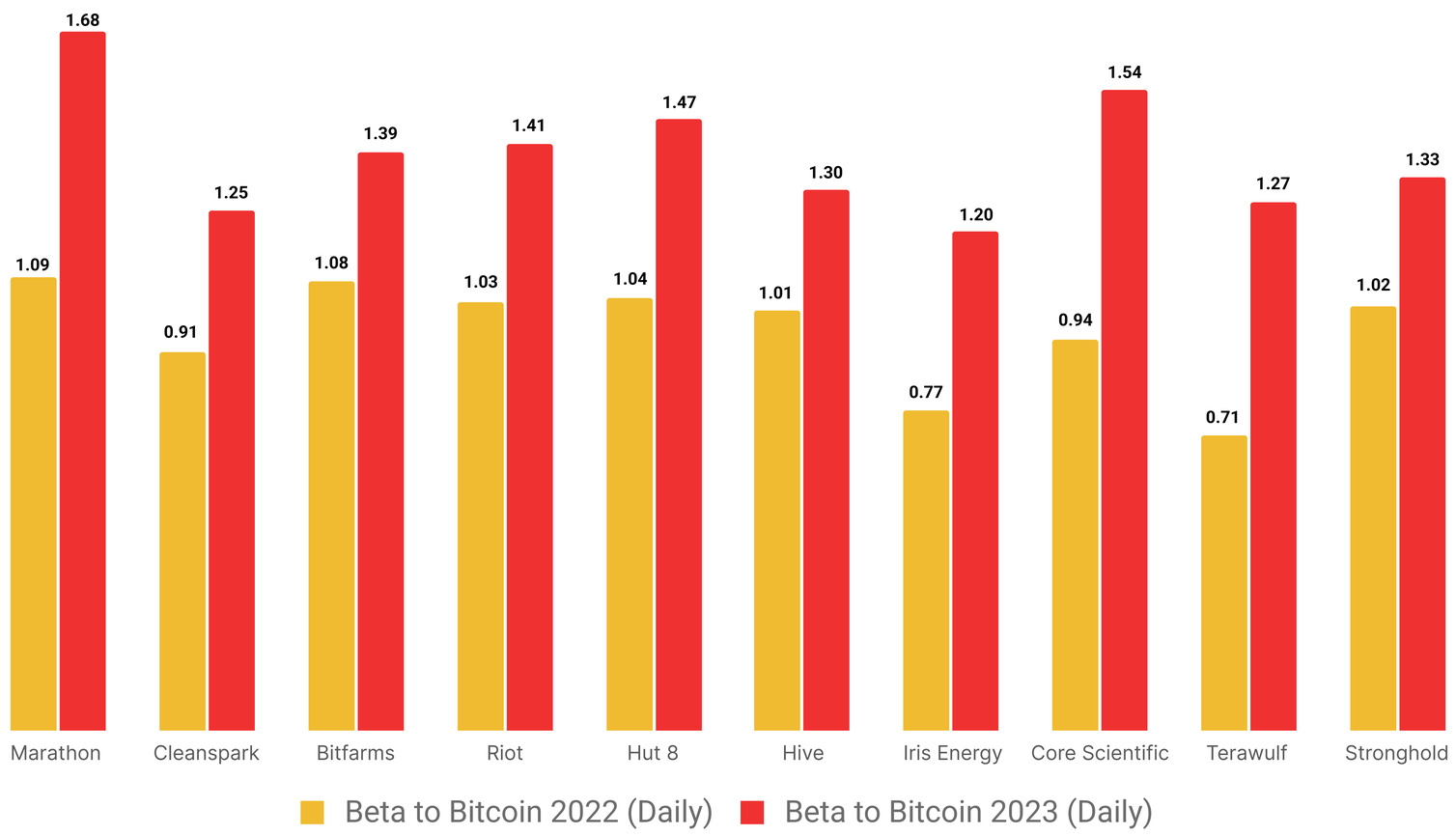
Source: Tradingview

Mining Stock Betas to Bitcoin

As we entered 2023, Bitcoin miners were still recovering from the brutal bear market in 2022. As the year progressed, bitcoin began a slow recovery higher into the summer months. As fall approached, Bitcoin traded within a tight range, but it surged above $40,000 in Q4-2023.

Based on the beta chart analysis below, Bitcoin mining stocks show correlation trends within bull or bear markets. During bear markets, you will notice that Bitcoin mining stock pricing movements are more correlated to Bitcoin's daily price fluctuations. In bull markets, you will notice a strong upside return to mining stocks relative to Bitcoin, as mining stocks have a strong beta to bitcoin. To time local bottoms, traders can observe that bitcoin miners have closer correlations to daily fluctuations in spot bitcoin price. As that trend breaks higher (>1.15 beta), Bitcoin miners are transitioning to a period of stronger returns.

Public Bitcoin Miners Daily Beta to Bitcoin (2022 vs. 2023)



* Chart includes public miners that have 2 full years of stock pricing data | Source: Yahoo! Finance

Taking a closer look at the individual mining companies shown in the chart, we can see that companies with strong balance sheets were more favored over companies with heavier debt loads in the bear market of 2022, as miners with heavier debt burdens had lower betas (for example, Iris Energy, Core Scientific, and Terawulf). At the time in late 2022, Iris Energy was in court settling their equipment debt obligations, Core Scientific filed for bankruptcy in late 2022, and Terawulf needed to negotiate new debt repayment terms with its lenders.

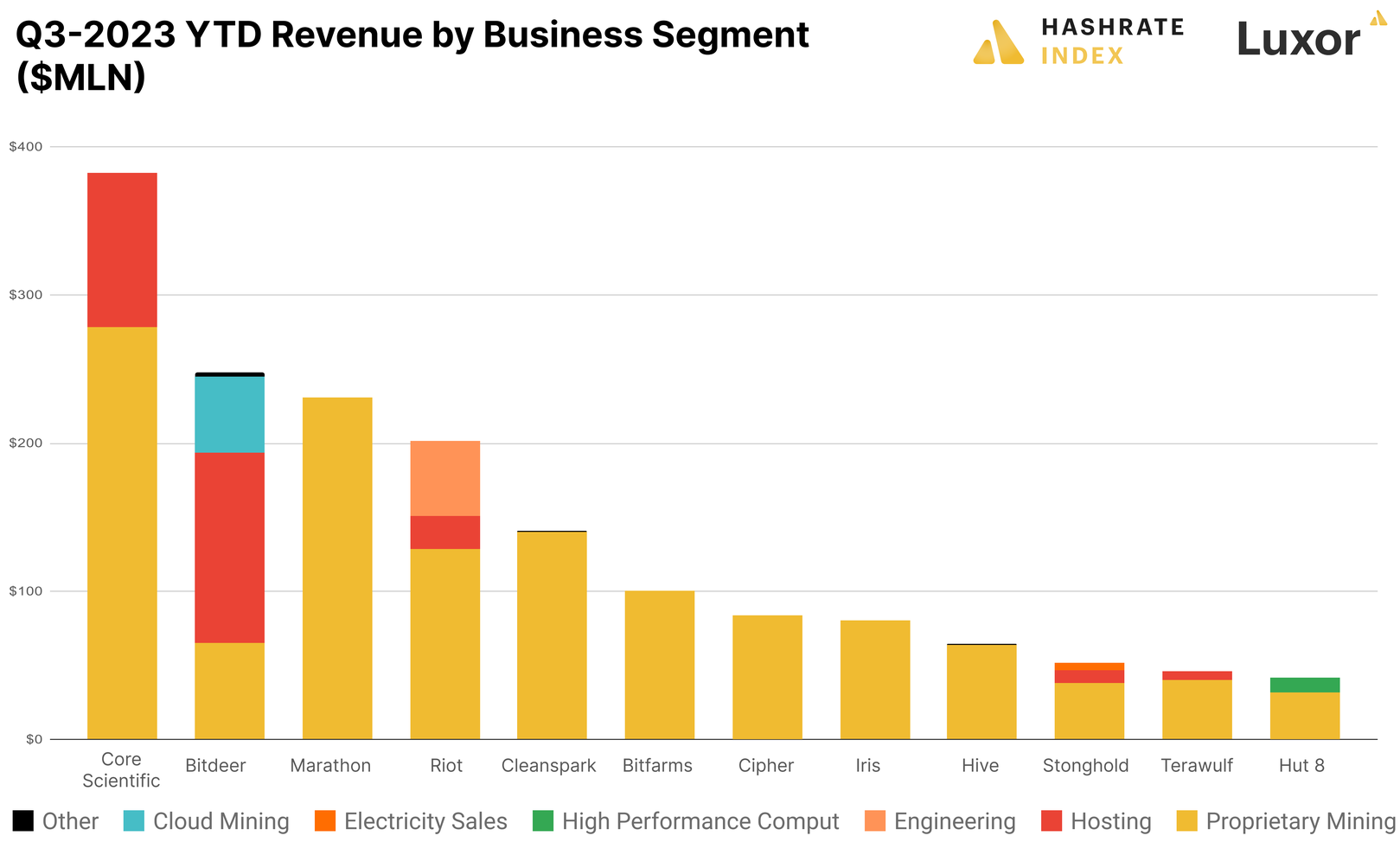
Bitcoin miners with higher average betas to bitcoin in 2022 generally had stronger balances sheets and strong operational hashrate performance. Cleanspark was likely discounted in the bear market after selling its entire Bitcoin stack and aggressively issuing shares to grow its business. In 2023, Cleanspark clearly showed much better performance after their expansion and acquisitions.

A clear observation in 2023: every miner had a higher positive correlation to the pricing movements of Bitcoin. At the start of 2023, bitcoin traded below $20,000, but by year-end, it was trading over $40,000. The market clearly rewards larger scale miners with stronger balance sheets. Core Scientific coming out of bankruptcy was an outlier, as investors started to price in the bull market for their business and re-listing on the Nasdaq.

Miners Continue to Diversify Revenue

As public Bitcoin miners mature from both a hashrate and operational standpoint, they are diversifying their revenue streams. Historically, a public miner might have drawn revenue primarily from proprietary mining (also called self mining) or hosting, but miners started making conscious efforts to expand their business segments in the last bull market, and 2023 saw this trend continue.

Q3-2023 YTD Revenue by Business Segment ($MLN)



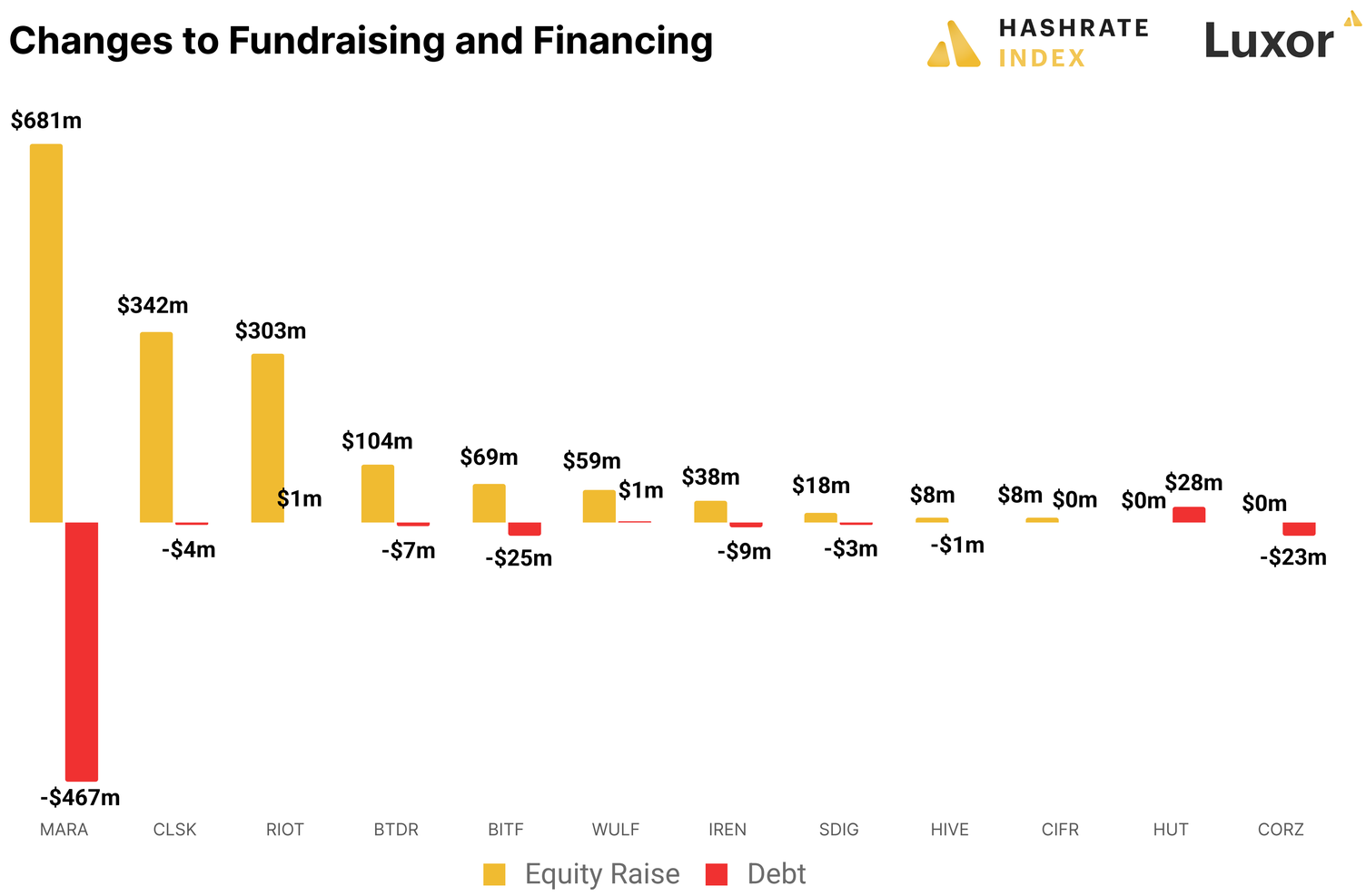
Source: Public disclosures

Riot and Bitdeer have perhaps the most diversified revenue streams, with the former continuing to draw revenue from its engineering arm and the latter drawing income from a trifecta mining strategy of proprietary, hosted, and cloud mining hashrate. Hut 8 provides an example of a miner who is looking beyond hashrate to generate revenue, as roughly a fourth of its revenue from Q1 to Q3 2023 came from the high performance compute data centers it purchased from Terago in 2022.

Public Miner Financing and Fundraising in 2023

Like all companies, public Bitcoin miners must continuously adjust their financial structures to adapt to varying market prices of equity and debt. Equity is now getting cheaper and easier to obtain due to the renewed bullishness in the sector, and the public miners are exploited this in 2023 by raising massive amounts of equity. Simultaneously, interest rates are relatively high after Central Bank rate hikes and miners want to keep their balance sheets nimble ahead of the halving, so we are seeing a reduction of debt in the sector.

As you can see in the chart below, four of the public miners raised more than $100 million worth of equity in the first three quarters of 2023. These were Marathon with $681 million, CleanSpark with $342 million, Riot with $303 million, and Bitdeer with $104 million.

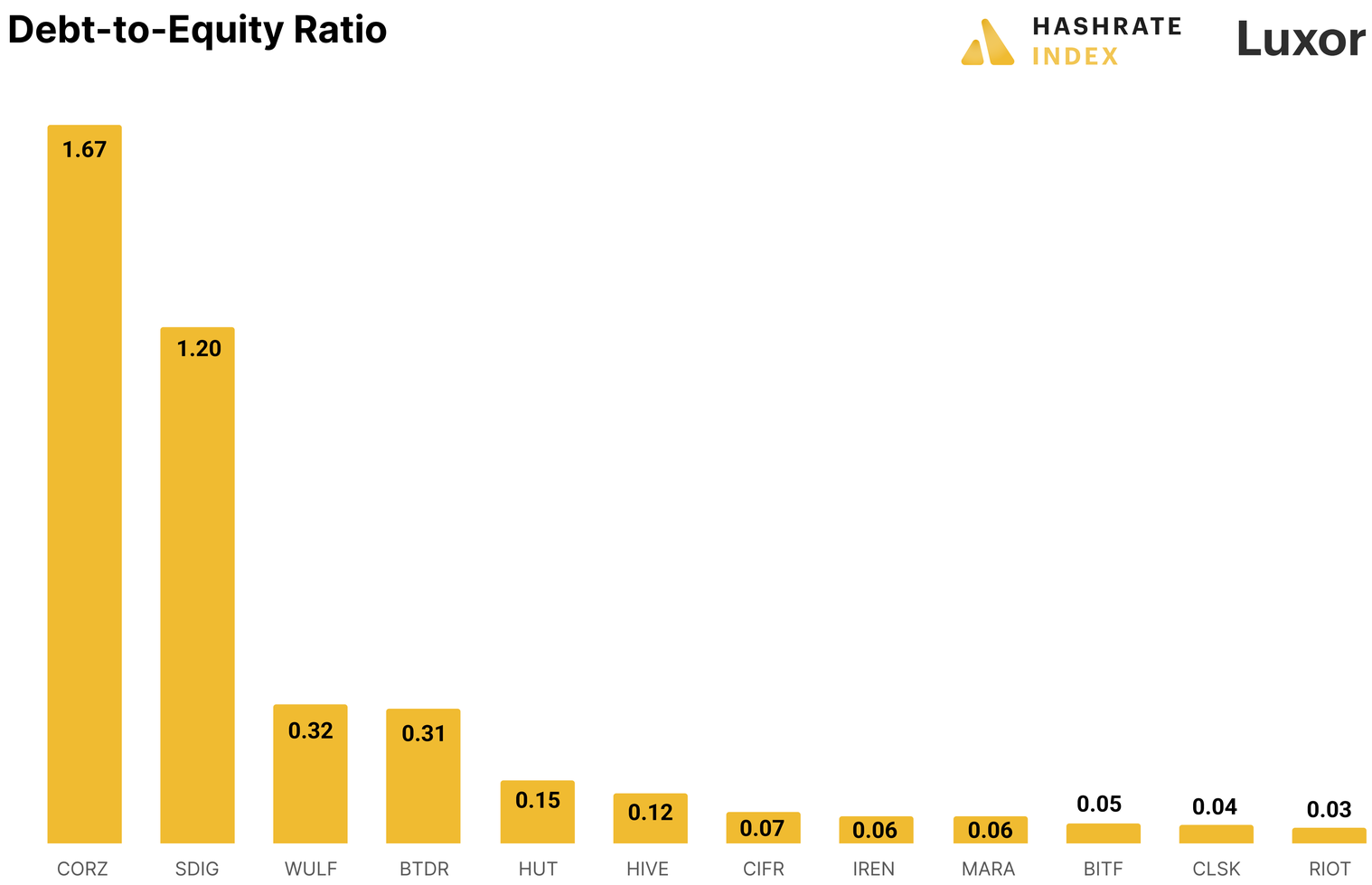


Source: Public Miners' Most Recent Financials

Last year, miners raised cash from equity to prop up their balance sheets ahead of the halving and to take advantage of low ASIC prices to expand their operations. Marathon paid down $417 million of its convertible debt, exchanging it for equity in order to save on interest rate payments and to achieve greater balance sheet flexibility ahead of the halving. In total, Marathon raised $681 million in 2023, including its debt-to-equity exchange.

A significant chunk of these equity raises were spent on massive ASIC purchases late in 2023. Many of these miners went public during the bull market of 2021 and early 2022, and now these public miners can expand in a counter-cyclical fashion for the first time. It's worth noting that, in 2023, equity raises were used to fund expansion, replacing the ASIC financing deals that were popular in 2021 and 2022. A handful of miners ended up defaulting on these high-interest loans, and financiers reclaimed the financed ASICs, which were often used to collateralize these loans. As interest rates rose in 2022 and 2023, these loans became untenable for Bitcoin miners, and as result, the ASIC financing landscape was all but dead last year, with no major ASIC financing deals taking place.

Indeed, on the chart above, we see that public miners are not raising debt, but are in fact reducing their total debt load. The miner who paid down the most debt over 2023 was Marathon at $467 million, with $417 million of this coming from the aforementioned convertible note reduction. Marathon is followed by Bitfarms, which paid down $25 million and now barely has any debt left.



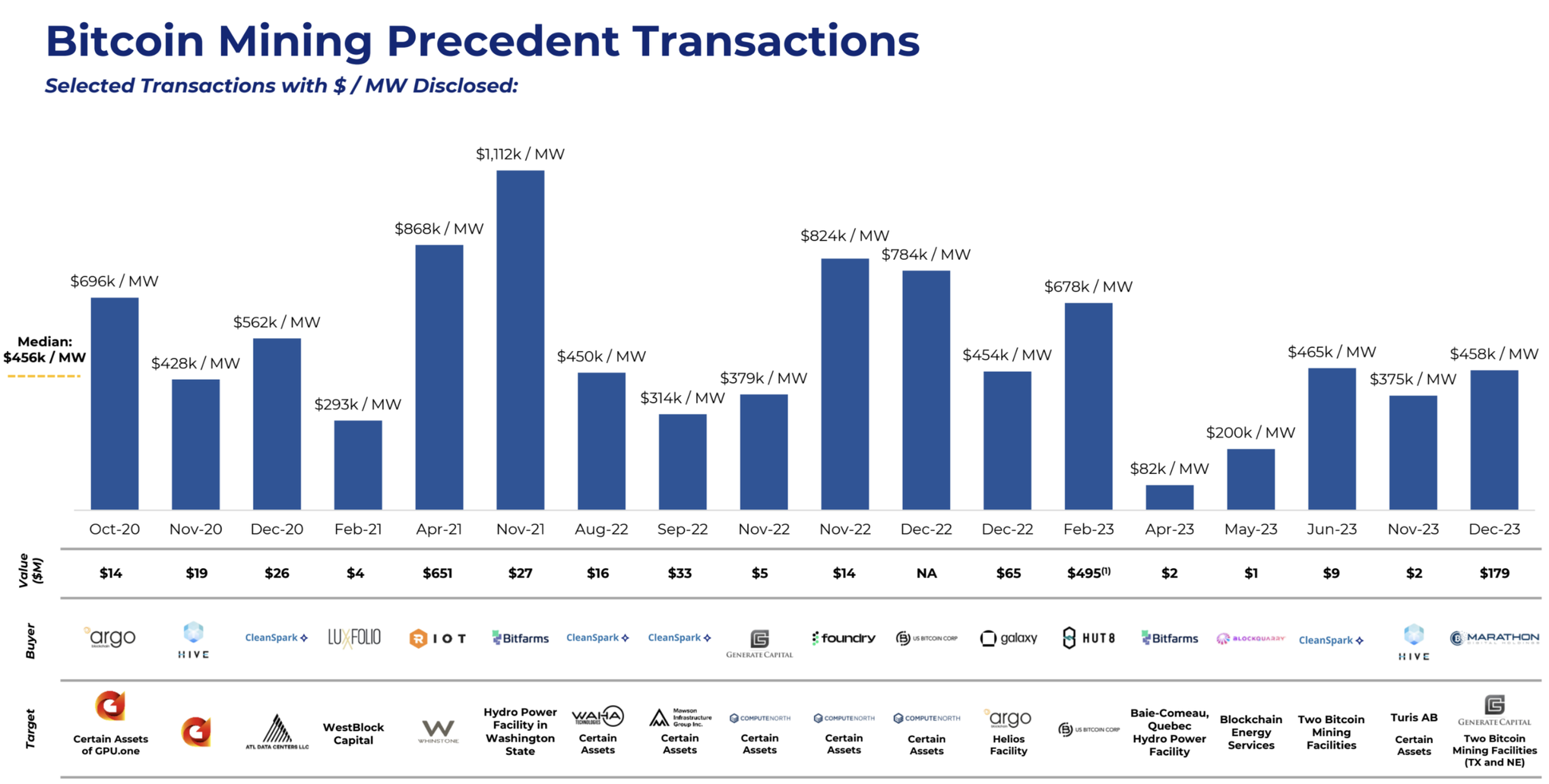
Source: Public Miners' Most Recent Financials, Tradingview

After these equity raises and debt reductions, the sector is now very financially strong ahead of the Fourth Halving. As you can see on the chart above, most of these companies have debt-to-equity ratios in a range of 0.3 or below, with Riot, CleanSpark, Bitfarms, Marathon, Iris Energy, and Cipher all scoring below 0.1. For reference, a debt-to-equity ratio below 1.5 is considered solid in most industries.

Just one year ago, many of these companies looked like they were extremely close to bankruptcy, but now most of them have turned around their situations and have incredibly solid balance sheets – a testament to how capricious this industry can be.

Public Miner Mergers and Acquisitions

In 2022, there was a flurry of mergers and acquisitions activity in the Bitcoin mining industry, a trend that blew into 2023. On a dollar basis, public Bitcoin miners committed more on M&A in 2023 than in 2022, with the majority of this value coming from Hut 8's merger with US Bitcoin Corporation and Marathon's purchase of two mining facilities from Generate Capital (this deal has not been finalized and is expected to close in the first half of 2024).



Source: FactSet; Pitchbook; Public filings, Cohen & Company Capital Markets intelligence

(1) Merger of equals. Deal value shown for USBTC based on USBTC's 50% pro forma ownership of the combined entity with a market capitalization of $990M

Source: Cohen & Company

We anticipate that 2024 will bring additional opportunities for distressed asset sales, mergers, and acquisitions as higher-cost and debt-heavy miners struggle to adapt to the reduction in Bitcoin's mining rewards.

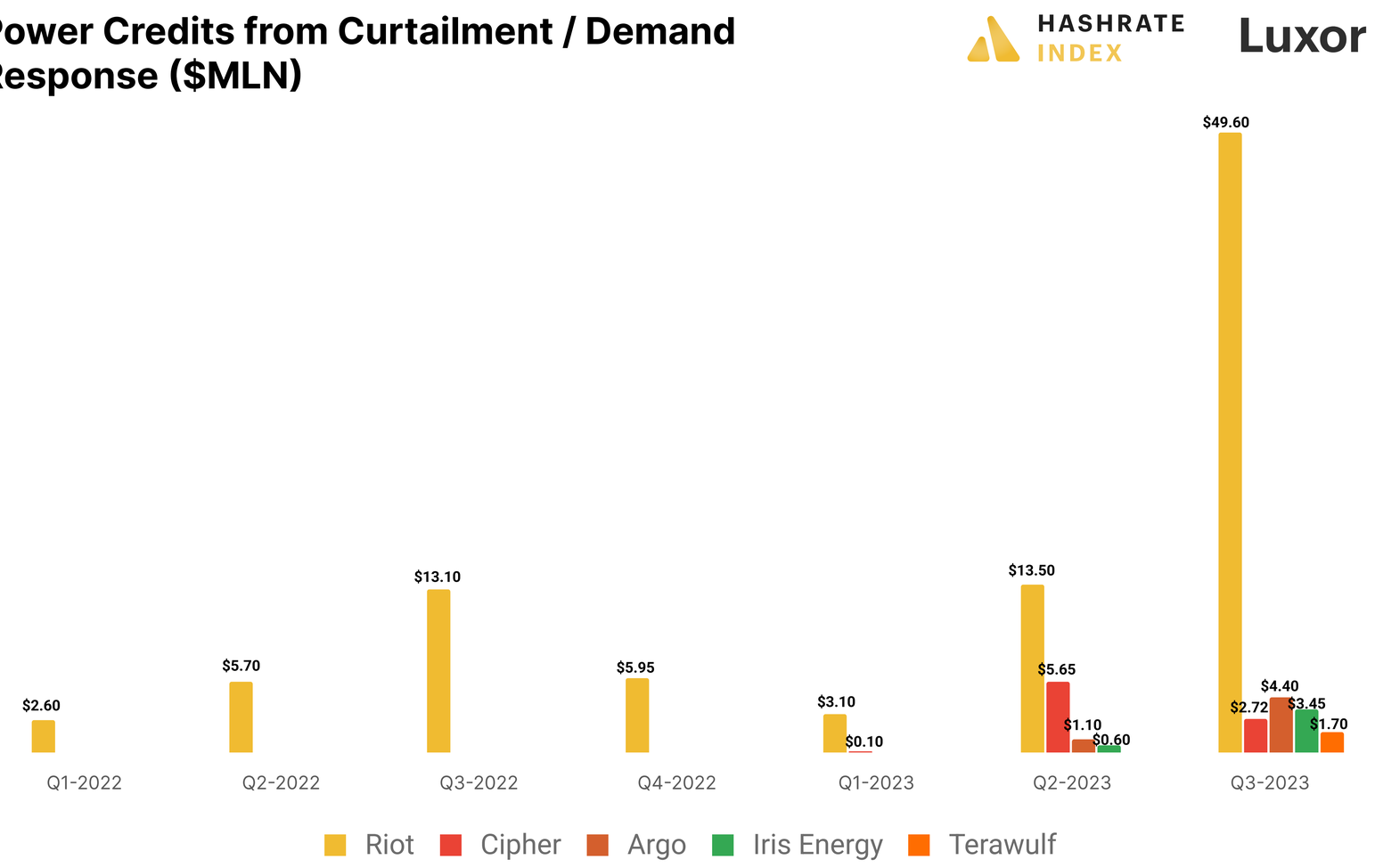
Public Miner Curtailment and Demand Response

More public miners adopted – or at the very least, began advertising – power curtailment and demand response strategies in 2023.

Depending on their power purchase agreements and contracts with power providers / local grid operators, industrial scale miners might have the ability to curtail their operations at times when the grid experiences stress and/or when the cost of power outpaces their ability to mine profitably. Sometimes, power companies/authorities may compensate miners for this demand response, usually in the form of a credit that they can apply to future power bills, but they may also curtail without being compensated. Additionally, some miners may be granted low power prices year-round in exchange for curtailment, a practice that is common with miners in Iceland and Canada. For those public miners who are compensated for these services, they increasingly took advantage of it in 2023, particularly in the summer months when grids experienced high demand or heatwaves created operational difficulties.

Texas has been the poster child of heatwave-induced grid stress. The state has a high penetration of renewable energy sources (namely, wind and solar), which can be highly intermittent and unreliable at certain times of the year; for example, ERCOT – Texas' power authority – typically budgets for wind turbines to provide 20% of Texas' power on any given day, so if a heatwave strikes and drops wind production below this threshold, then the grid experiences disruptions and price spikes. These disruptions and price spikes have become increasingly more common, and miners have increasingly helped fill in the gap by curtailing operations to free up power for the grid.

Power Credits from Curtailment / Demand Response ($MLN)



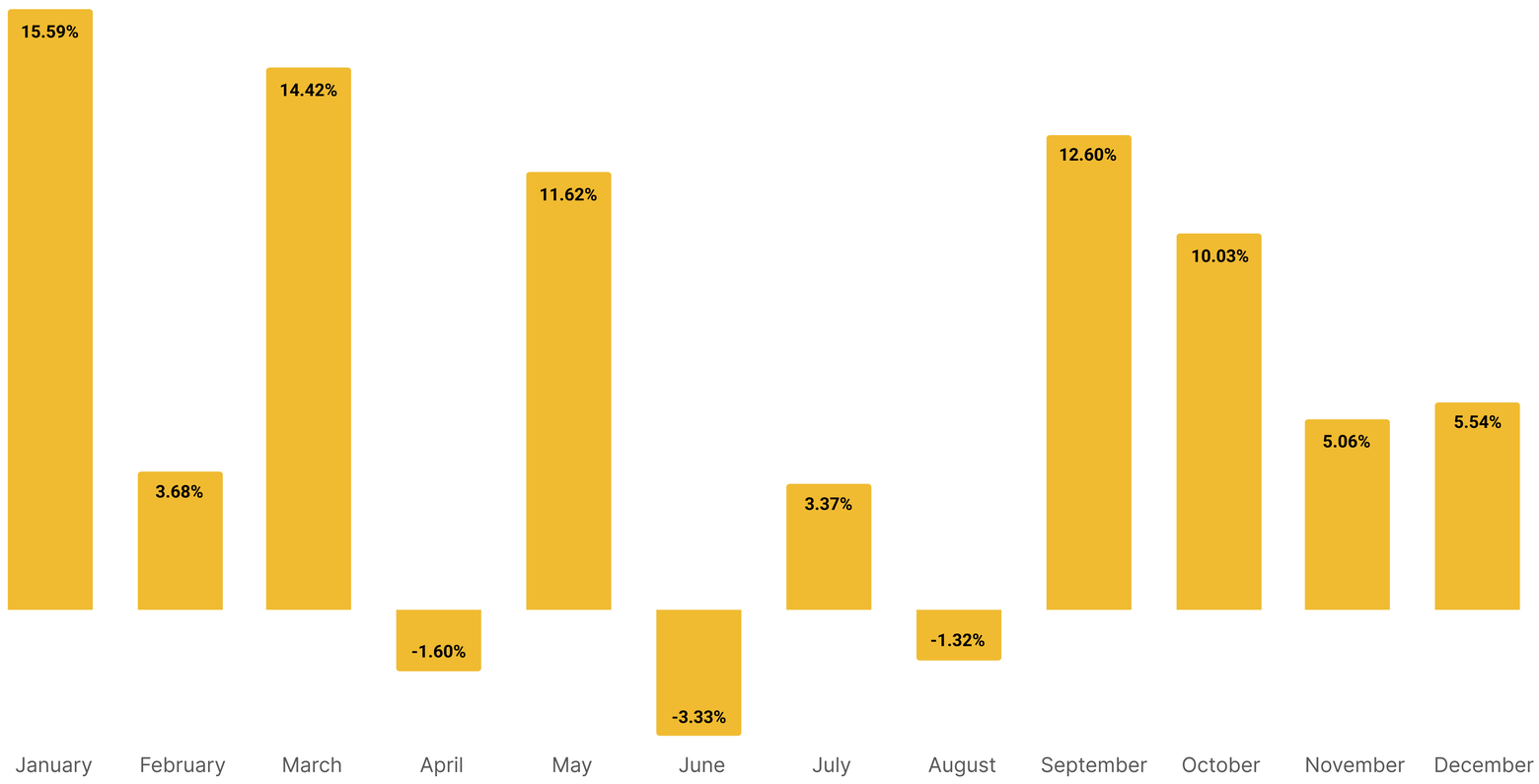
Source: Public disclosures

As the chart above shows, Riot has been the biggest practitioner of these services, netting $66.2 million in power credits from the practice in the first three quarters of 2023 and $49.6 million in Q3 alone. These credits are the driving force behind Riot's incredibly low power costs.

Curtailment from industrial-scale miners is impacting a new pattern of hashrate seasonality for the Bitcoin network. Prior to China's mining ban, Bitcoin's hashrate would expand during the wet season (May - September) as miners in the region of Szechuan took advantage of gushes of excess hydro-power, and it would contract in the dry season as miners unplugged and migrated to coal-rich regions like Xinjing and Inner Mongolia.

Now, Bitcoin's hashrate is more likely to dip in the summer months as heat – primarily in North America – affects power grids and Bitcoin mining operations. As the chart below illustrates, Bitcoin's hashrate contracted by 3.33% in June and 1.32% in August, and while it did increase in July, this was the lowest month of growth for Bitcoin's hashrate in 2023. Conversely, the winter's colder months invited growth, with January and March delivering the largest percentages of expansion for Bitcoin's hashrate in 2023.

Bitcoin's Hashrate (7-Day Avg.) Monthly Change in 2023



Source: Hashrate Index

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Forthcoming and Forestalled Public Miners

2023 delivered multiple developments for private miners who went public or who had their public dreams thwarted.

- Bitdeer: Jihan Wu's latest venture began trading on the Nasdaq Exchange in April after an IPO
- Phoenix Group: UAE-based miner Phoenix Group debuted on the Abu Dhabi Securities Exchange in December. Public information on the miner is scarce, but it manages some 100 MW of mining operations in the UAE, Canada, and the US.
- Griid: Griid's long road to public markets ended on January 2, 2023 when it listed on the Cboe Canada Inc. exchange. Griid had been attempting to go public since 2021 by merging with a special acquisition company, and its public aspirations took a blow in December when its SPAC, Adit EdTech Acquisition Corporation, said it would delist itself from the NYSE American exchange after the exchange said that it would not approve a post-merger listing. Griid completed its merger with Adit EdTech Corporation on December 29 and proceeded with its listing on Cboe Canada.
- BitFuFu: Cloud mining giant BitFuFu canceled its plans to go public via a SPAC IPO in February of 2023, a time when Bitcoin mining stocks were languishing in the wake of Q4-2022's Bitcoin market carnage.
- Rhodium: Texas-based Bitcoin miner Rhodium had its public market hopes dashed in October when its reverse merger partner, SilverSun Technologies, withdrew from the business combination. Previously, Rhodium had canceled its IPO plans in November of 2022 to conduct the reverse-merger.

8

Mining Pools and Firmware Landscape

Mining Pool Leaderboard

Below, we show the top 10 Bitcoin mining pools by year by blocks mined from 2017-2023. Mining pool competition is a fierce race to offer the best features, strongest compliance, and highest payouts. Pools are consistently targeting each other's clients and finding ways to win them over. Maintaining a place on the leaderboard is a tough task, with only a few pools pulling it off over the years.

Rank	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21	Dec-22	Dec-23
1	ANTPOOL	BTC.com	BTC.com	f2pool	f2pool	foundry	foundry
2	BTC.TOP MINING POOL	ANTPOOL	f2pool	Poolin	ANTPOOL	ANTPOOL	ANTPOOL
3	f2pool	SLUSH POOL	Poolin	BTC.com	Poolin	f2pool	f2pool
4	BTC.com	ViaBTC	ANTPOOL	ANTPOOL	ViaBTC	BINANCE POOL	ViaBTC
5	ViaBTC	BTC.TOP MINING POOL	SLUSH POOL	Huobi	BINANCE POOL	ViaBTC	BINANCE POOL
6	BTCC	f2pool	ViaBTC	ViaBTC	BTC.com	Poolin	MARATHON DIGITAL HOLDINGS
7	BITFURY	Unknown	BTC.TOP MINING POOL	58COIN&1THash	foundry	BTC.com	Luxor
8	SLUSH POOL	Poolin	Unknown	OKEX	SLUSH POOL	SLUSH POOL	BTC.com
9	BIXIN	DPOOL	Huobi	BINANCE POOL	Huobi	Luxor	BRAIINS POOL
10	BWPool	BITCLUB NETWORK	BITFURY	SLUSH POOL	Luxor	SBI Crypto	Poolin

Source: Hashrate Index

Miners Converge on FPPS

In 2023, we saw strong market convergence on full pay-per-share (FPPS) pools as miners continue to show a preference for more stable and consistent payout structures. The market has voted, and that vote is on Full-Pay-Per-Share (FPPS) payment methodology as the preferred method for miners. This is a result of miners preferring low variance of payouts and being averse to mining luck. If transaction fees become a material part of mining reward we may see a reversal in this trend; however, for now it's clear that miners prefer FPPS.

Payout Method Marketshare	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21	Dec-22	Dec-23
FPPS Pools	0%	28%	54%	67%	66%	67%	87%
PPS+ Pools	22%	23%	24%	27%	30%	29%	10%
PPLNS Pools	59%	49%	22%	6%	5%	5%	3%
PPS Pools	19%	0%	0%	0%	0%	0%	0%

Source: Hashrate Index

Since 2018, there have been many mining pools that closed down by some combination of failure to gain market share, solvency issues, or aversion to mining luck risk. The table below displays the mining pools that signed at least one block in previous years but failed to mine a block in the labeled year, as well as three pools that publicly announced they shuttered their operations in 2023 . Following this methodology, 67 pools have become defunct in the past 6 years.

Defunct Pools	2018	2019	2020	2021	2022	2023
1	Waterhole	HashBX	sigmapool.com	BitFury	Bitcoin.com	OKExPool
2	PHash.IO	Helix	Eobot	MiningCity	ArkPool	mmpool
3	HAOZHUZHU	BitcoinIndia	okpool.top	BytePool	Huobi.pool	OKKONG
4	EkanemBTC	BTPOOL	DPOOL	TATMAS Pool	NovaBlock	OKMINER
5	Telco 214	GBMiners	58COIN	58COIN&1THas	Rawpool	Sigmapool.com
6	MiningKings	BWPool	tigerpool.net	CKPool	BTC.TOP	Pega Pool
7	GoGreenLight	ConnectBTC	BitMinter		Minerium	Titan
8	mmpool	Bitfarms Pool	1M1X		KanoPool	Urkel
9	BATPOOL	Rawpool.com	BitcoinRussia		SpiderPool	
10	DCExploration	haominer	Bixin		WAYI.CN	
11	DCEX	BTCC	Hummerpool		Lubian.com	
12	7pool	CanoePool	SecretSuperstar		TMSPool	
13	BCMonster	tiger	BitClub		EclipseMC	
14	1Hash	Bitcoin-Ukraine				
15	Eligius					
16	EXX&BW					

Source: Luxor Business Data

Firmware Provider Landscape

The ASIC miner firmware landscape continues to expand, with ePIC Blockchain and Luxor releasing their proprietary firmware in 2023. Both ePIC and Luxor aim to compete with Braiins and Vnish, two well established firmware providers who have been developing firmware since 2018.

Company	Domiciled	Released	Firmware Type	Model
ePIC UMC	Canada	2023	Proprietary	Purchase
Luxor Firmware	USA	2023	Proprietary	Subscription
Braiins OS	Czechia	2018	Proprietary	Subscription
Vnish.com	Russia	2018	Proprietary	Subscription

Source: Luxor Business Data, Public Disclosures

ePIC Blockchain, a Toronto, Ontario Canada based company started 2023 by releasing their proprietary firmware compatible with S19, M30, and M50 series ASICs; ePIC distributes this firmware by selling their proprietary UMC control boards, a monetization choice that has diverge from the traditional firmware subscription (a.ka., the developer fee) revenue model that most firmware providers use. Instead of charging miners a fee in real time in the form of hashrate, ePIC requires its clients to purchase and install their control board, which entitles miners to use ePIC's proprietary firmware without any subscription fee. While the additional capital expense and labor required to change out hardware can be prohibitive to some groups of miners, there's value in fleet standardization when it comes to manufacturer hardware changes. For example, Bitmain has moved onto their fourth and possibly fifth iteration of control boards with the release of the S19k Pro and S21, making it challenging for firmware providers to continue supporting new generation miners..

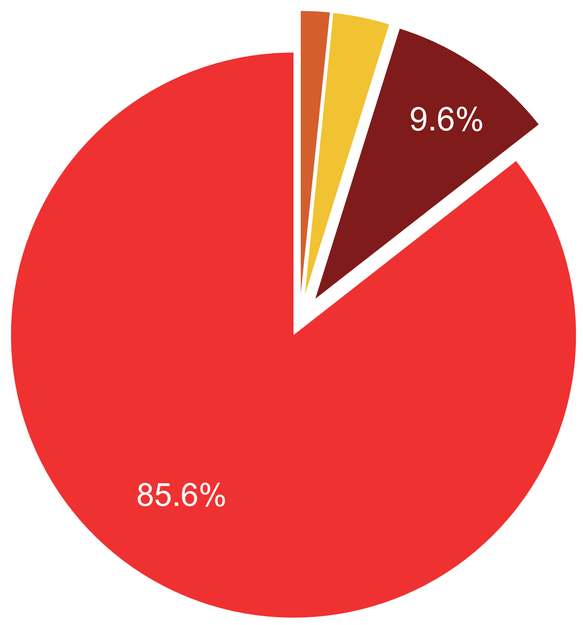
Control Boards Supported per ASIC Series				
Series	**Xilinx**	**BeagleBoard**	**mLogic**	**CVITEK**
S19 Series	✓	✗	✗	✗
S19 Hydro	✓	✗	✗	✗
S19j Pro	✗	✓	✓	✗
S19 Pro Hydro	✓	✗	✗	✗
S19 Pro+	✗	✓	✓	✗
S19 XP	✗	✗	✓	✓
S19 XP Hydro	✗	✗	✓	✓
S19k Pro	✗	✗	✓	✓
S21	✗	✗	✓	✓
S21 Hydro	✗	✗	?	?

Source: Luxor Business Data, Public Disclosures

In early Q2 2023 Luxor launched its firmware, LuxOS. Like Luxor Pool, LuxOS was the first firmware product that was designed and built from the ground up by a US based company. With the goal of helping educate miners on the benefits of increasing uptime, operation stability through clock speeds and thermal management, Luxor has been able to quickly gain market share. While manufacturer technical changes and uncertainty pose longer term challenges for all firmware developers, Luxor has quickly inserted itself as a technical expert as it relates to firmware and best in class miner operations.

After-Market Firmware Marketshare

HASHRATE INDEX Luxor

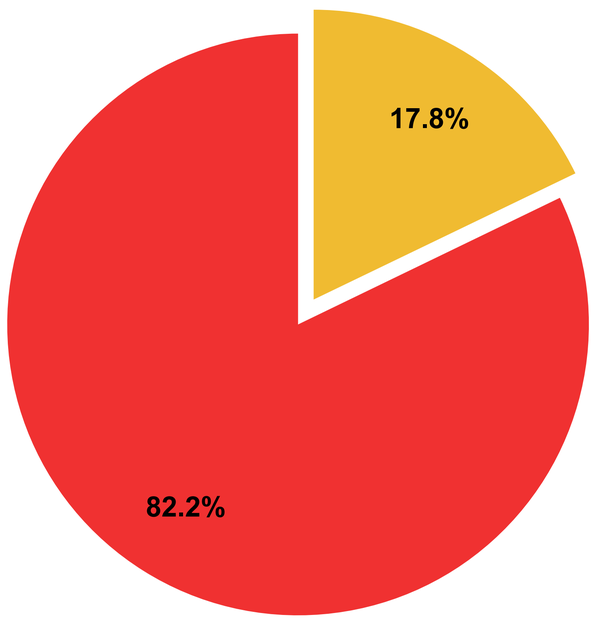


Source: Luxor Business Data

Looking back in history, Braiins (formerly Slush Pool), domiciled in Prague, Czechia has been researching and developing aftermarket firmware since mid 2018. Leveraging the public and private information that came to light in 2017 regarding Bitmains overt ASICBoost, Braiins quickly realized that there was opportunity to improve ASIC efficiency through bmminers code called multi-version. In order to support this new bitstream Braiins began developing BraiinsOS with the goal of replacing CGminer with their open source version, BOSminer. Jumping ahead to March 2020, Braiins released BraiinsOS+ which included their new autotuning feature. Since Braiins' original ASICBoost public announcement in 2018, interest in performance-improving firmware dramatically increased. Through 2020, Braiins has steadily introduced novel features that include per chip autotuning functionality, dynamic power scaling, and a range of support tools to assist miners with batch configurations and operation management. To date, Braiins continues to push the industry forward with their suite of product offerings and tools.

While Braiins has become perhaps the most publicly facing firmware provider with its open source development, Vnish, domiciled in Eastern Europe, has quietly been building and supporting firmware since 2017 (and perhaps before). While not much is publicly known about the team, Vnish can be considered as an industry behemoth that has typically focused on the Russian and Asian markets. In addition to pioneering features and model support that are common to all firmware providers today, Vnish has become popular with clients as it allows them to whitelabel their product and split the subscription (DevFee). While this can create a better user experience for distributors and incentivizes broad distribution, this can also reduce fee transparency between clients. Regardless, as competition increases, the Vnish team continue to build out model support and iterate on features at an impressive rate.

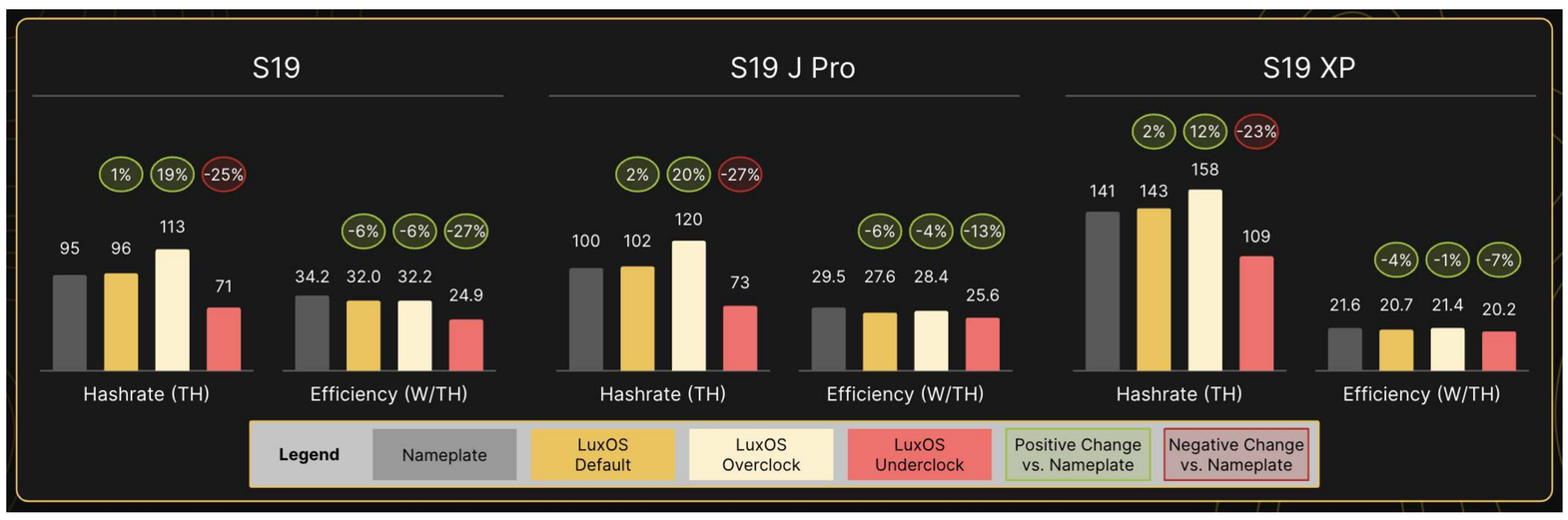
After-Market Firmware Adoption



Source: Luxor Business Data

Firmware Performance

After-market firmware provides users with the ability to augment a machine's out-of-the-box performance by adjusting factory set operating parameters. More precisely, aftermarket firmware can adjust the voltage and frequency at which a machine's ASIC chips operate, providing the ability to underclock (i.e., reduce voltage and/or frequency to reduce power consumption) and overclock (i.e., increase voltage and/or frequency to increase power consumption). Generally, underclocking leads to lower hashrate but better J/TH efficiency (i.e., the machine produces more hashrate per unit of power consumed), while overclocking produces higher hashrate and worse J/TH efficiency. As such, firmware unlocks a much wider range of performance ability for machines compared to their stock profile. In testing for Luxor's LuxOS firmware on S19 series models, changing firmware voltage and frequency settings allowed for a 20%+ hashrate increase when overclocking and a 25%+ J/TH efficiency improvement when underclocking.



Source: Luxor Business Data

With the ability to augment their machine's performance using firmware, operators can select settings that maximize their margins given their operating cost profile and current hashprice conditions. As an example, suppose a miner with an S19j Pro (100 TH/s) and a $0.065 per kWh cost of power is deciding whether to run their machine at stock or install firmware to underclock or overclock their machine. Using a hashprice of $90/PH/day and LuxOS performance data to demonstrate over/underclocking performance, it's clear that the miner should be using firmware to overclock their machine given the 25% increase in miner margin compared to stock.

	Stock	LuxOS Underclock	LuxOS Overclock	Row	Equation
TH / unit	100	73	120	A	
Watts / unit	2,950	1,871	3,390	B	
Hashprice	$90.00	$90.00	$90.00	C	
Pool/Firmware Fees	2.50%	2.80%	2.80%	D	
Revenue	**$8.78**	**$6.39**	**$10.50**	E	= C x (D / 1000) x (100% - D)
Power Rate	$0.065	$0.065	$0.065	F	
Power Cost	**$4.60**	**$2.92**	**$5.29**	G	= G x (B / 1000) x 24
Miner Margin	**$4.17**	**$3.47**	**$5.21**	H	= E - G
% Delta vs. Stock		*-17%*	*25%*		

Source: Luxor Business Data

Now, suppose hashprice suddenly shifts and tests historic lows at $50/PH/day. In this case, underclocking would be the optimal strategy as miner margin is 130% greater than with stock firmware.

	Stock	LuxOS Underclock	LuxOS Overclock	Row	Equation
TH / unit	100	73	120	A	
Watts / unit	2,950	1,871	3,390	B	
Hashprice	$50.00	$50.00	$50.00	C	
Pool/Firmware Fees	2.50%	2.80%	2.80%	D	
Revenue	**$4.88**	**$3.55**	**$5.83**	**E**	**= C x (D / 1000) x (100% - D)**
Power Rate	$0.065	$0.065	$0.065	F	
Power Cost	**$4.60**	**$2.92**	**$5.29**	**G**	**= G x (B / 1000) x 24**
Miner Margin	**$0.27**	**$0.63**	**$0.54**	**H**	**= E - G**
% Delta vs. Stock		*130%*	*99%*		

Source: Luxor Business Data

By utilizing firmware and adjusting settings based on market conditions, miners with an actively managed firmware strategy stand to outperform their counterparts who rely solely on manufacturer-default firmware.

Firmware Adoption & Network Resiliency Ahead of the Halving

Throughout 2023, miners were heavily focused on enhancing their operational efficiency amid a period of historically low hashprice. Despite the recent uptick in hashprice, which may have muted profitability concerns in the near-term, miners are likely to refocus on efficiency as we move closer to – and succeed – the Fourth Halving.
Miners that implement after-market firmware strategies will be better prepared for any potential hashprice decline from the Halving. With the ability to underclock using firmware, operators can improve their machine's J/TH efficiency by as much as 25% and ultimately lower their breakeven hashprice (i.e., the hashprice at which they would no longer be profitable).

Currently, the use of firmware is modest, but its wider adoption could significantly lower both the J/TH efficiency and breakeven hashprice of the overall network. Consequently, this could enable the network hashrate to continue its upward trajectory, even in the face of a hashprice decline.

As a benchmark, the current network breakeven hashprice is $38.40 per PH per day assuming no firmware usage, estimated network efficiency of 32 J/TH (per Coin Metrics), and an estimated average operating cost of $50 per MWh. The implied network hashrate at this breakeven hashprice would be 654 EH with a BTC price of $45,000 and post-halving block rewards of 3.875 BTC (3.125 BTC subsidy plus 0.75 BTC in transaction fees). If firmware adoption increases — say to 30% — and operators enhance their J/TH efficiency by 15% as a result, the network breakeven hashprice would be reduced to around $36.7 per PH per day. The implied network hashrate would also increase to 685 EH.

J/TH		Firmware Adoption										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
J/TH Improvement	0%	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
	5%	32.2	32.0	31.9	31.7	31.6	31.4	31.2	31.1	30.9	30.8	30.6
	10%	32.2	31.9	31.6	31.2	30.9	30.6	30.3	29.9	29.6	29.3	29.0
	15%	32.2	31.7	31.2	30.8	30.3	29.8	29.3	28.8	28.3	27.9	27.4
	20%	32.2	31.6	30.9	30.3	29.6	29.0	28.3	27.7	27.0	26.4	25.8
	25%	32.2	31.4	30.6	29.8	29.0	28.2	27.4	26.6	25.8	25.0	24.2

Breakeven Hashprice		Firmware Adoption										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
J/TH Improvement	0%	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64	$38.64
	5%	$38.64	$38.45	$38.25	$38.06	$37.87	$37.67	$37.48	$37.29	$37.09	$36.90	$36.71
	10%	$38.64	$38.25	$37.87	$37.48	$37.09	$36.71	$36.32	$35.94	$35.55	$35.16	$34.78
	15%	$38.64	$38.06	$37.48	$36.90	$36.32	$35.74	$35.16	$34.58	$34.00	$33.42	$32.84
	20%	$38.64	$37.87	$37.09	$36.32	$35.55	$34.78	$34.00	$33.23	$32.46	$31.68	$30.91
	25%	$38.64	$37.67	$36.71	$35.74	$34.78	$33.81	$32.84	$31.88	$30.91	$29.95	$28.98

Implied Hashrate (EH)		Firmware Adoption										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
J/TH Improvement	0%	650	650	650	650	650	650	650	650	650	650	650
	5%	650	653	656	660	663	667	670	673	677	680	684
	10%	650	656	663	670	677	684	691	699	706	714	722
	15%	650	660	670	680	691	703	714	726	738	751	765
	20%	650	663	677	691	706	722	738	756	774	792	812
	25%	650	667	684	703	722	743	765	788	812	839	866

Note: Breakeven hashprice calculated as J/TH x 24 Hours x $/kWh power rate. Implied hashrate calculated as (144 blocks per day x 6.875 BTC per block) / (breakeven hashprice / BTC price)

Source: Luxor Business Data

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Significant Regulatory and Legislative Action in 2023

Since China's Bitcoin mining ban, hashrate has increasingly spread to new locations. As a result – and as Bitcoin increasingly becomes an accepted asset – governments and regulators around the world have rolled out legislation and regulation to address the industry. The laws and regulations can at times be beneficial or detrimental to the Bitcoin mining industry, but more often than not, they are simply attempts to codify Bitcoin mining into existing legal and regulatory structures.

2023 was perhaps one of the most active years for policy proposals and formal government action directed toward the Bitcoin mining industry. In the US, 2023 was marked by significant state-level action to regulate the industry, including so-called "right to mine" laws that sought (and sometimes succeeded) to establish legal protection for Bitcoin mining entities by treating them like data centers.

Global Bitcoin Mining Regulations, Legislation, and Policy Proposals in 2023

HASHRATE INDEX Luxor

January 1
Oregon House introduces House Bill 2816 to curb energy use from data centers and Bitcoin miners (failed)

January 16
Mississippi House introduces House Bill 848 (Mississippi Digital Asset Mining Bill), which prohibits electricity rate discrimination against Bitcoin miners and other protections (pending)

January 16
Mississippi House introduces Orphaned Well Cryptocurrency Mining Partnership Program (failed)

January 26
State of New York proposes Task Force to Study Economic Empowerment Zones "to study the potential designation of economic empowerment zones for the mining of cryptocurrencies in the state of New York" (pending)

February 2
Illinois Senate Bill 1239 proposed, which amends Illinois' Civil Administrative Code to include cryptocurrency miners in data center classification (pending)

February 6
Oklahoma Senate proposes Senate Bill 443 to establish the Orphaned Will Bitcoin Mining Partnership Program (pending)

March 7
Missouri House passes the Digital Mining Protection Act, which defends the right to run a full Bitcoin node, prohibits electricity rate discrimination against Bitcoin miners, and subjects miners to the same treatment as data center companies (pending)

March 9
Oklanhoma Senate proposes the Commercial Digital Asset Mining Act, which (among other things) establishes certain sales tax exemptions for Bitcoin miners (pending)

March 9
Texas House introduces the Orphaned Well Bitcoin Mining Partnership Program (pending)

March 9
Russia Duma revises Bitcoin mining bill to impse jail time on miners who fail to report incpme

April 1
New laws for stringent Bitcoin mining taxation come into effect

March 9
Biden administration introduces Digital Asset Mining Energy excise tax (aka DAME tax) as part of its 2024 budget proposal; DAME provision failed to pass in Congress

April 6
Arkansas House and Senate pass the Arkansas Data Centers Act of 2023, which guarantees same legal treatment for Bitcoin miners as traditional data centers

April 13
Montana House and Senate passes bill that protects "the right to mine digital assets" and guarantees same legal treatment for Bitcoin miners as traditional data centers

May 6
Washington Governor Jay Inslee signs House Bill 1416 into law, which places emissions limits on data centers and Bitcoin mining farms

May 16
The European Union green lights comprehensive cryptocurrency regulations, which includes such measures as transaction tracing; new regulations to be implemented in 2024

May 30
Texas Senate Bill 1751, which would limit Bitcoin miners' ability to participate in demand response, fails in the Texas House

June 22
Amendmenet that exempts miners from the Goods and Services Tax/ Harmonized Sales Tax receives royal ascent

July 1
Sweden abolishes tax incentives for data center operators, including Bitcoin miners

August 8
Angola government proposes a bill to ban Bitcoin mining

October 3
Uzbekistan's National Agency for Perspective Projects issues decree stipulating that miners must receive a state permit to operate

November 8
New Brunswick bans N.B. Power from granting power allotments to new Bitcoin mining facilities

December 4
Kenya's National Assembly's Finance and National Planning Committee introduces amendment to the Capital Markets Bill of 2023 to establish tax code for cryptocurrencies and Bitcoin mining

December 13
Pennsylvania House passes Bill 1476, which institutes reporting requirements for Bitcoin miners and establishes a study for Bitcoin mining's environmental impact

December 8
Angola parliament passes bill to establish regulatory framework for cryptocurrencies and Bitcoin mining

December 21
Argentinian government ratifies law to make bitcoin legal tender for contract settlement

December 22
Nigerian Central Bank lifts ban on bank accounts for crypto companies

10

Predictions for 2024

The 2024 Bitcoin Halving will no doubt leave an indelible mark on the current Bitcoin mining market and reshape its landscape.

While the 2020 halving didn't directly cause the event, China's 2021 Bitcoin mining ban and the subsequent Great Hashrate Migration have defined the Third Halving Epoch (2020-2024) and furnished the conditions for a mining market that has been markedly different from the Second Halving Epoch (2016-2020).

We believe that the Fourth Halving Epoch (2024-2028) will bring about even greater change and could be accompanied by yet another redistribution of Bitcoin's hashrate to new geographies. For 2024 and the coming years, we (loosely) predict the following:

- North America's hashrate dominance will wain. In the second halving epoch, China dominated the Bitcoin network's hashrate share, occupying anywhere from 70-90% of total hashrate at its peak. This balance of power shifted to North America following China's mining ban, with the US and Canada collectively capturing roughly 50% (give or take) from the summer of 2021 up to the present. We expect that the continent's share of the global hashrate has peaked and will recede after April 2024's halving drops the block subsidy to 3.125 BTC. Miners will increasingly look elsewhere for cheaper electricity after their margins are compressed, with South America, Africa, and other under-explored areas primed to capture significant growth.
- In North America, retail hosting-as-a-service begins to decline as lower mining margins squeeze out both hosts and clients.
- Mergers, acquisitions, and distressed asset sales will pick up in 2024 and 2025 amid a compressed hashprice environment.
- Inscriptions and alternative uses for block space in 2024 will result in transaction fee levels that are on par -- or higher -- than 2023's average.
- Given the recent approval of various bitcoin ETFs, we expect that Bitcoin mining stocks will lose some of their investment premium as vehicles for bitcoin exposure, as investors will now have more direct exposure through a number of bitcoin ETFs.