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2024 Bitcoin Halving Impacts and Implications

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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

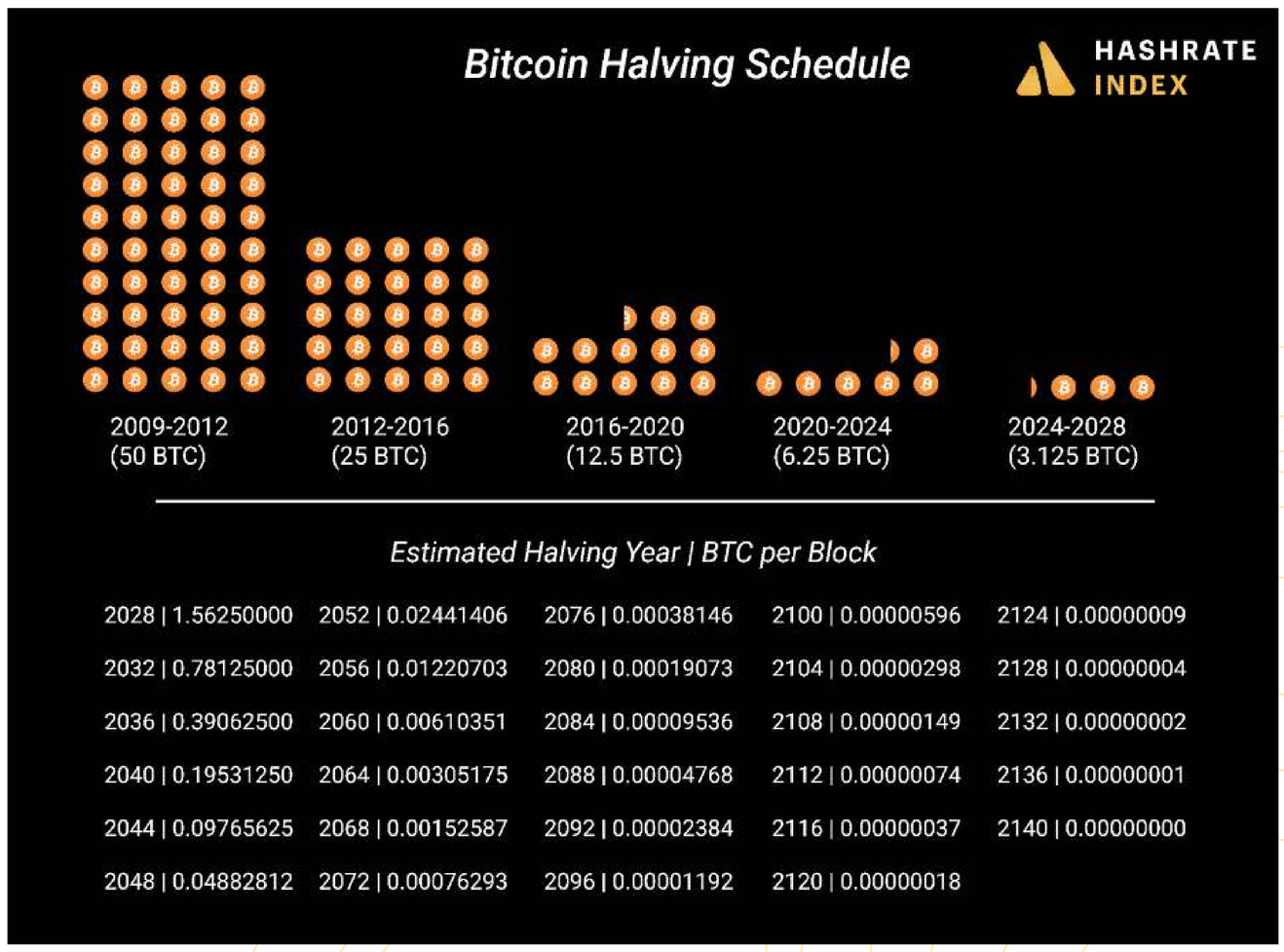
2024 Bitcoin Halving: Impacts and Implications

The Halving is one of the many attributes that makes Bitcoin truly unique in the realm of financial assets. No other major commodity has a completely calculable production schedule with a foreknown supply shock event that cuts the commodity's production in half.

The Bitcoin Halving is a quadrennial event that programmatically reduces Bitcoin's block subsidy – the new bitcoin that miners generate in each block they mine – in half. The next Bitcoin Halving will occur at block height 840,000, which we currently estimate will come to pass on April 19, 2024. We arrived at this estimate using the average block time since 2020. Below, we present a table that provides a range of plausible Halving dates using various block time averages as of 17:12 UTC on March 20, 2024.

Avg. Block Time to Halving	Halving Time
10 min 20 sec	April 21, 2024 at 14:54 UTC
10 min 10 sec	April 21, 2024 at 2:33 UTC
10 min	April 20, 2024 at 14:12 UTC
9 min 50 sec	April 20, 2024 at 01:51 UTC
9 min 40 sec	**April 19 2024 13:30 UTC**
9 min 30 sec	April 19, 2024 at 01:09 UTC
9 min 20 sec	April 18, 2024, at 12:48UTC
9 min 10 sec	April 18, 2024, at 00:27 UTC
9 min	April 17, 2024, at 12:06 UTC

The upcoming event will be Bitcoin's Fourth Halving and it will reduce the block subsidy from 6.25 BTC to 3.125 BTC. Bitcoin's block subsidy will halve every four years until approximately the year 2140, after which point Bitcoin's block subsidy will hit 0 and miner revenue will subsist exclusively from transaction fees.



The 2020 Halving left an indelible mark on the Bitcoin mining sector, and the 2024 Halving will no doubt similarly effect significant changes. Bitcoin mining – a sector that used to be the domain of garage-shop hobbyists – has progressed into a multi-billion dollar, global industry, where the landscape is dominated by industrial-scale miners in public and private markets who manage hundreds of megawatts and have backing from traditional financial firms.

Put differently, the scope and scale of the industry – both in terms of its collective size and the size of individual mining entities – have never been bigger, and there's never been more at stake for its participants. To address the potential impacts of the event, we've drafted this report to examine how the Halving will impact core Bitcoin mining metrics like hashrate, difficulty, and hashprice, and we extrapolate this analysis to evaluate how the halving may impact ASIC markets, hosting contracts, public miners, and other aspects of the sector. We also analyze potential geographic regions that could provide miners with lower cost options and which may see growth after the Halving as miners relocate from higher cost areas.

The main takeaway from our analysis is one that bucks the usual predictions that analysts make when discussing the Halving: given Bitcoin's price appreciation in 2024, it's conceivable that an insignificant sum of hashrate comes offline after the Halving – in fact, it's plausible that no hashrate will come offline at all immediately after the event. Of course, the amount of hashrate that comes offline will be dependent on the path of Bitcoin price and transaction fees.

Summary of Findings

Based on our analysis, we provide the following takeaways:

- The Fourth Bitcoin Halving will occur on April 19, 2024 at approximately 13:30 UTC.
- If Bitcoin's current price holds or increases moderately, we estimate ~3-7% of Bitcoin's hashrate may come offline after the halving, and we will see these approximate percentage decreases reflected in subsequent difficulty adjustments. If Bitcoin's price drops from its current level to ~$48,000, then we estimate ~16% of Bitcoin's hashrate could come offline.
- We anticipate that Bitcoin's year-end hashrate will range between 639-674 EH/s

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Bitcoin Mining Economic Outlook After the Halving

The Bitcoin Halving is a storm cloud on the horizon, and its primary impact on block rewards is certain: Bitcoin miners will receive a significant, negative revenue shock in the short term.

The secondary impacts of this event – on Bitcoin price, network difficulty, and transaction fees – are uncertain and debated.

Some argue the decrease in Bitcoin's supply issuance will increase Bitcoin price, pointing to the performance of Bitcoin price after the three previous Halvings. Others point to the fact that the Halving is a certainty, and should be "priced in." That is, the event itself should have no impact on Bitcoin's price, as rational investors would have already factored it into their valuations of bitcoin, and the similarities between previous "cycles" is a poor predictor of future outcomes.

When examining how the Halving will affect mining revenue, transaction fees are the wild card. In two separate periods in the past year, transaction fees have spiked substantially, like they did after the last Halving. However, those surges failed to sustain for more than a few weeks and hashrate forward markets have not priced in high transaction fees at the far end of the forward curve. Nevertheless, our quantitative models project a moderate increase in transaction fees heading into and after the halving, and the qualitative commentary surrounding ordinal/inscription activity is bullish.

A corresponding drop in network difficulty from a decline in hashrate is perhaps the most debated and consequential aspect of the Halving. For Bitcoin miners, hosters, lenders, hashrate traders, and financial market participants planning for the future, it is important to consider a range of plausible scenarios, review a variety of forecasting methods from a number of different sources, and understand relationships between hashprice, hashrate, difficulty, and other key variables.

To help determine the outlook for hashprice, hashrate and difficulty after the halving, we conducted a systematic review using both quantitative and qualitative projection techniques, including:

- Luxor's univariate and multivariate forecasting of hashprice components;
- Luxor's Bitcoin mining supply and demand model scenarios and outputs;
- Luxor's Bitcoin Hashrate Forwards market pricing;
- Third party projections;
- Case studies of the previous halvings; and
- Commentary on the ordinal/inscription market around the upcoming halving.

Based on our review of the data and current economic conditions, we estimate that only ~3-7% of the network hashrate will come offline after the halving. However, with the impact of the event highly uncertain and highly dependent on Bitcoin price and transaction fees, any estimate in the 0-40% range is reasonable. The lower Bitcoin price and transaction fees, the higher the proportion of network hashrate will turn off due to unprofitability.

Estimates for Halving Impact on Bitcoin Hashrate	Estimated % of Network Hashrate Coming Offline at Halving	Assumptions	
		BTC Price	Tx Fee
Luxor Stress Case	**32%**	**$30,000- $31,000**	**0.1**
Coinshares	~24%	n.a.	n.a.
Galaxy	~17%	$45,000	0.55
Luxor Bear Case	**16%**	**$46,000 - $48,000**	**0.2**
2020 Halving	15%	n.a.	n.a.
2012 Halving	13%	n.a.	n.a.
Implied Luxor Hashrate Forward's Market	**7%**	**62,500**	**0.25**
Luxor Flat Case	**7%**	**64,500**	**0.34**
2016 Halving	5%	n.a.	n.a.
Luxor Base Case	**3%**	**$66,000 - $68,000**	**0.34 - 0.64**
Luxor Bull Case	**0%**	**$67,000 - $70,000**	**1.5 - 2.5**
Luxor Super Bull Case	**0%**	**$69,000 - $78,000**	**3.125**

During previous halvings, network difficulty bottomed after two negative adjustments following the halving, only to rebound to all-time highs shortly thereafter. Luxor's base case anticipates a similar rebound that will put difficulty at an all-time high at the end of 2024.

Estimates	2024 EOY Hashrate (EH/s)	Assumptions	
		BTC Price	Tx Fee
Luxor Stress Case	**389**	**$29,000 - $30,000**	**0.1**
Coinshares	550	n.a.	n.a.
Galaxy	700	$45,000 - $50,000	0.55
Luxor Bear Case	**501**	**$43,000 - $44,000**	**0.2**
2020 Halving	n.a.	n.a.	n.a.
2012 Halving	n.a.	n.a.	n.a.
Luxor Flat Case	**607**	**64,500**	**0.34**
2016 Halving	n.a.	n.a.	n.a.
Luxor Base Case	**639**	**$70,000 - $72,000**	**0.64**
Luxor Bull Case	**671**	**$81,000 - $84,000**	**2.5**
Luxor Super Bull Case	**674**	**$104,000 - $109,000**	**3.125**

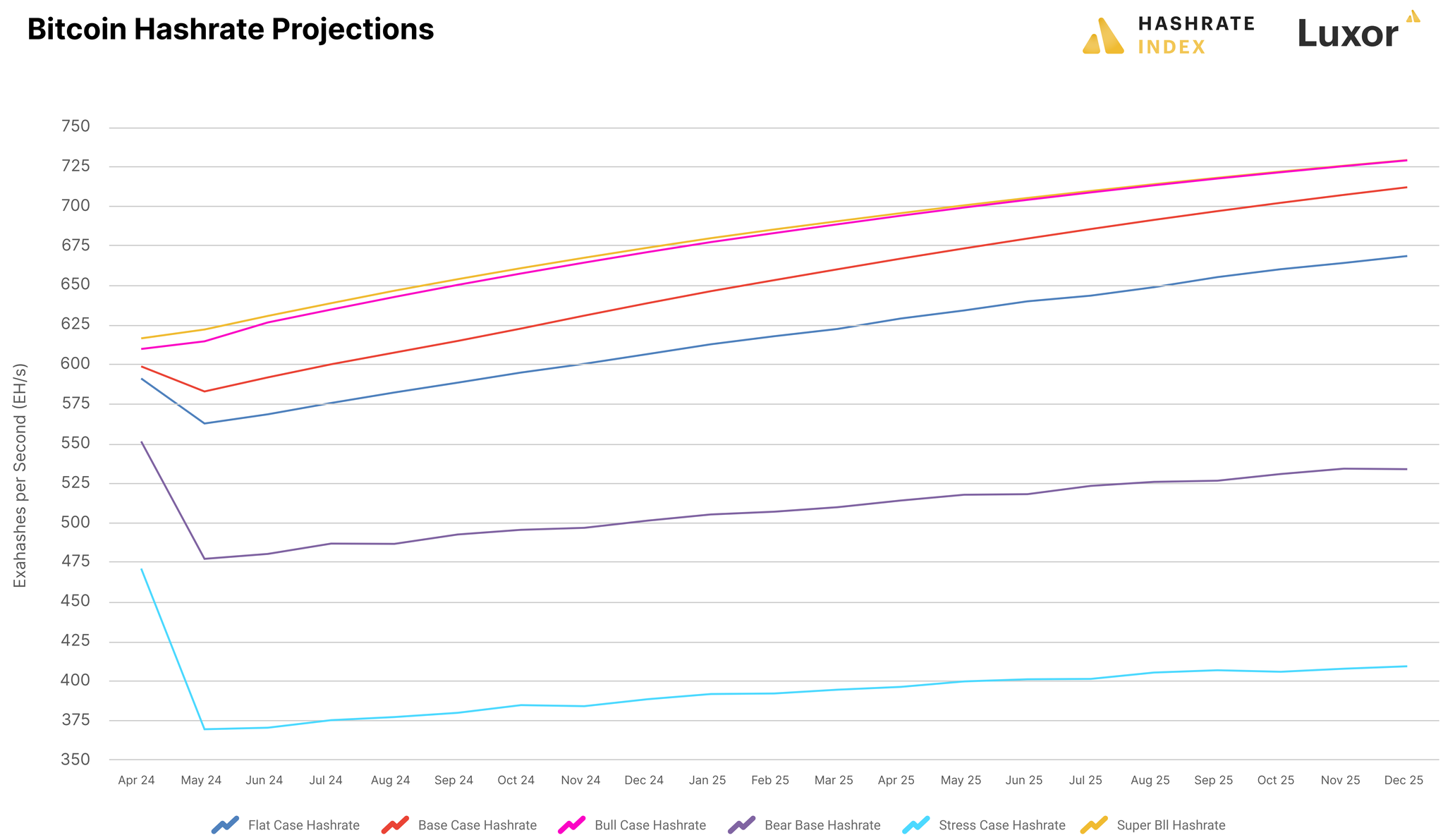
Luxor's Hashprice, Hashrate, and Difficulty Projections

The following projections were generated by Luxor's supply and demand model for Bitcoin mining hashrate, difficulty and hashprice. The model factors in Bitcoin price, transaction fees, and block subsidy on the demand side, and global ASIC hashrate capacity and profitability estimates on the supply side. We use Luxor's full pay per share (FPPS) hashprice methodology to estimate demand for hashrate and Luxor's industry knowledge and internal data on global Bitcoin Mining ASIC production and global ASIC operator profitability to estimate supply. The interactions of these various supply and demand inputs determine the model's hashrate, difficulty, and hashprice outputs.

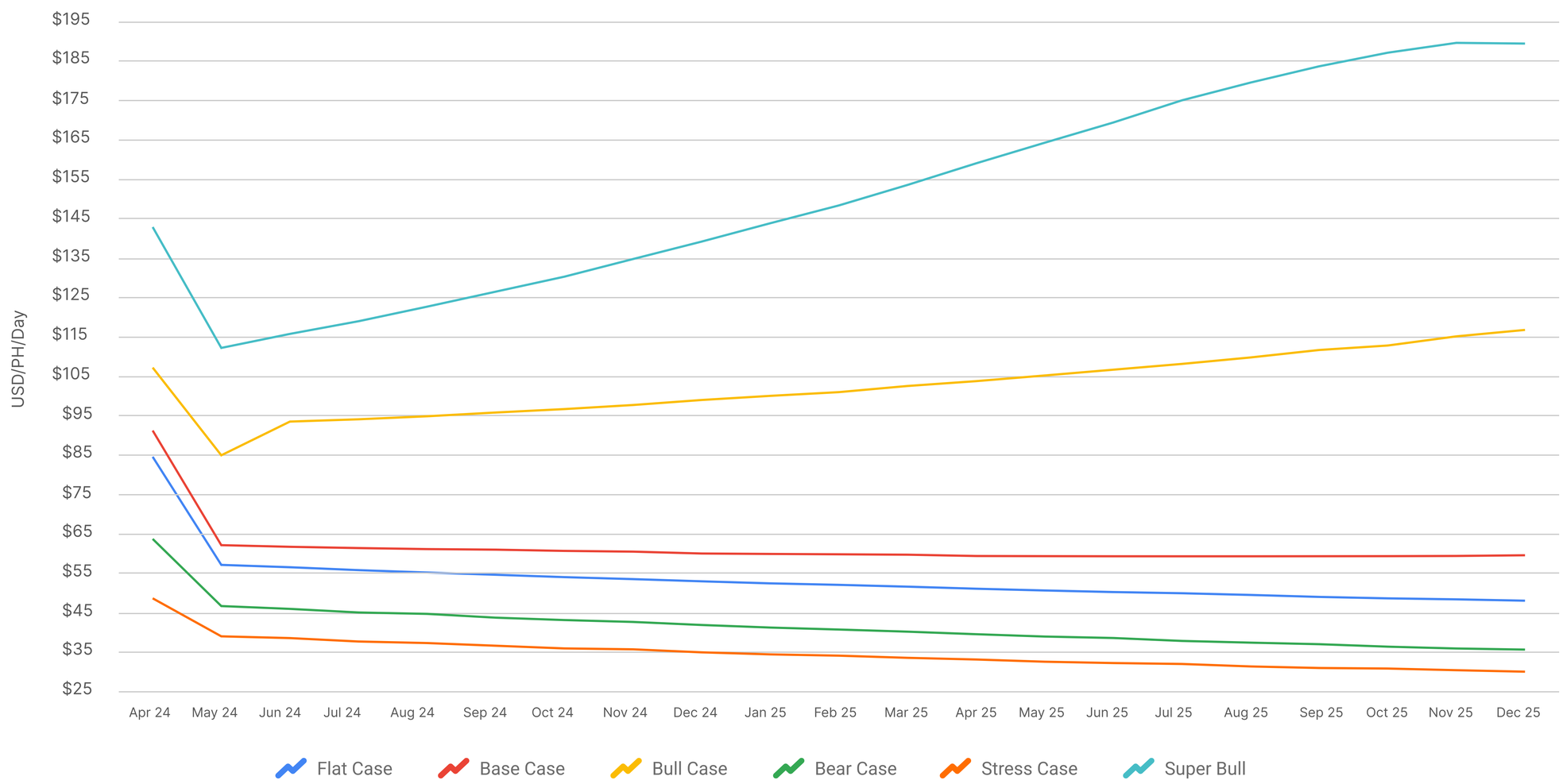
The model outputs include hashrate, difficulty, BTC-denominated and USD-denominated hashprice. Equilibrium hashprice in each scenario is defined as the point where hashrate supplied equals hashrate demanded. In economics, equilibrium is the state in which supply and demand are balanced, and prices and quantities have had time to adjust to changes in external forces. The results are calibrated to estimate monthly averages for each of these variables. The table below describes each output from the model.

Please keep in mind that any model's results must be interpreted with caution. A model is a simplified mathematical representation of a system. It can be used to further understand the mechanics of a system and conduct scenario analysis under various assumptions. It is not a completely accurate detailed mapping of the entire Bitcoin mining economy or prediction for the future. Different assumptions will produce different results.

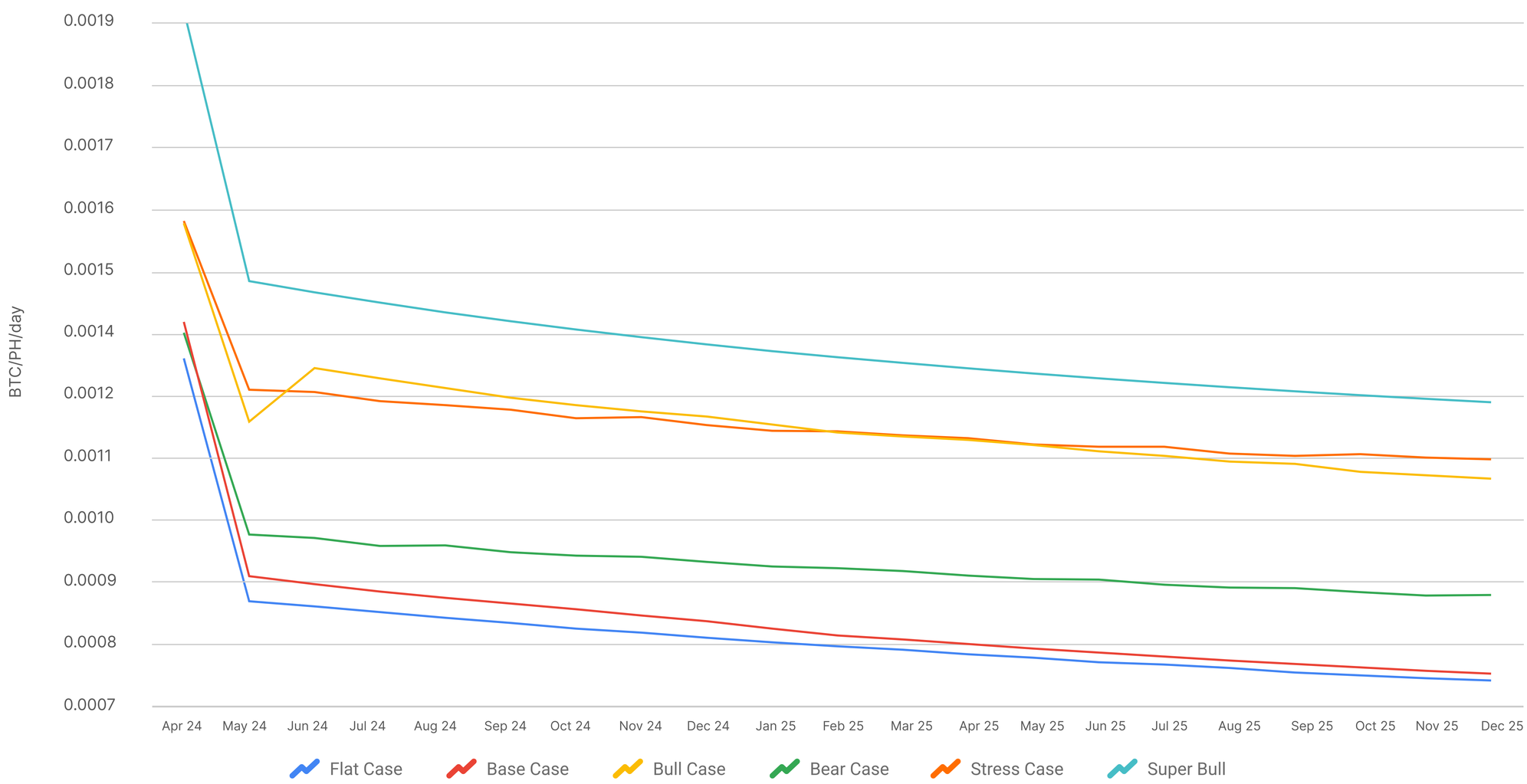
(To see our full analysis and model assumptions, please refer to the appendix at the end of this report).



USD-Denominated Hashprice Projections

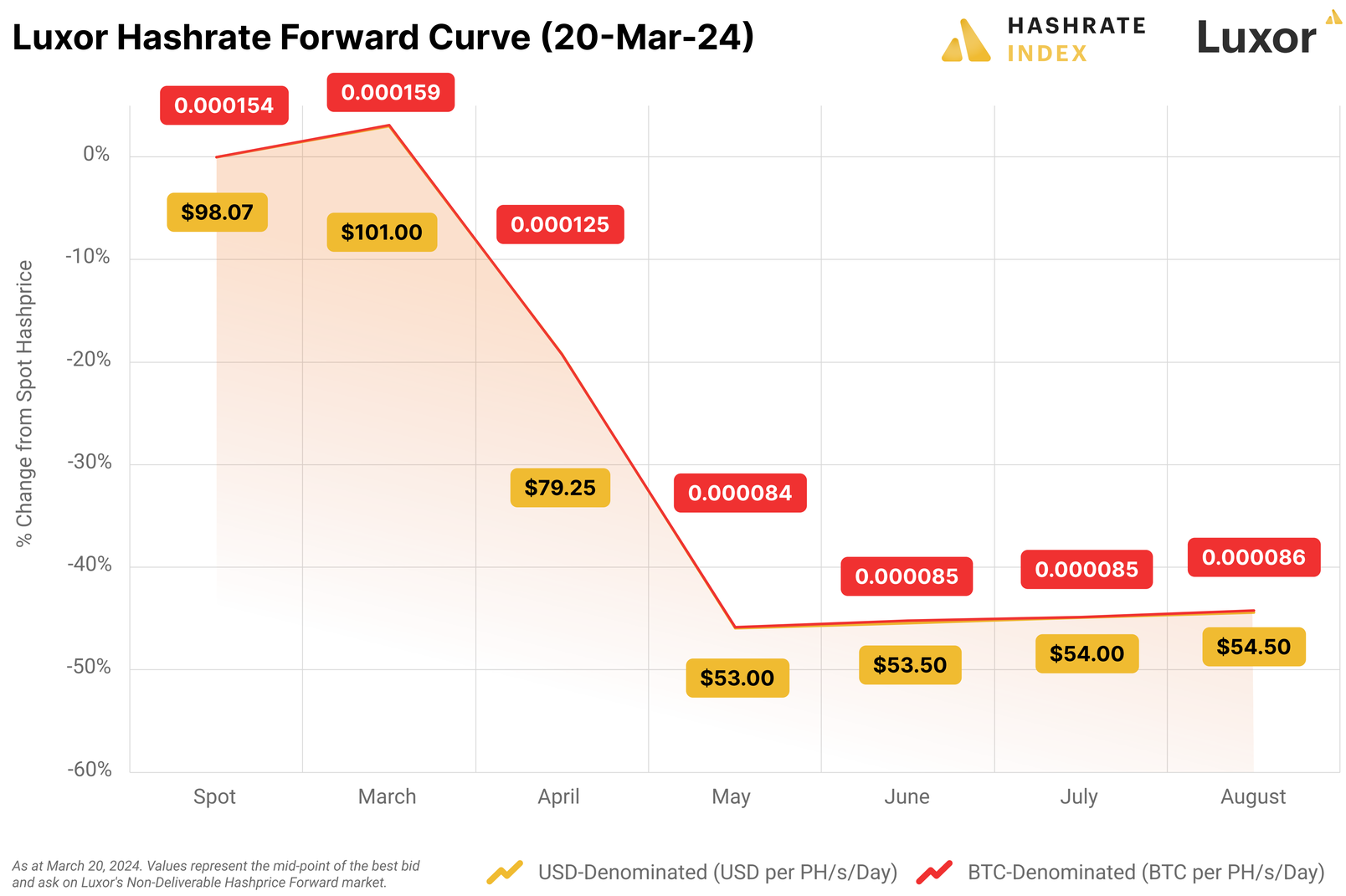


BTC-Denominated Hashprice Projections



Luxor Hashrate Forward Curve

Based on the most recent Hashrate Forward curve from Luxor's Derivatives Desk, Bitcoin hashrate traders are pricing in post-halving hashprice at $53/PH/day, which is roughly in-line with our flat case hashprice projection. We can assume based on this forward curve that Bitcoin miners are expecting either falling difficulty or rising transaction fees to lift up hashprice in the immediate aftermath of the Halving, a not-unreasonable expectation given previous halvings and the positive impact inscriptions have had on transaction fees.



Projections From Other Sources

Galaxy Digital's Forecast

In their year-end report for 2023, the Galaxy Digital Research team presents their own projections for Bitcoin's hashrate in 2024.

Galaxy Digital's projections apply a range of outcomes. Their methodology begins by estimating a hashrate ceiling for the network in 2024, with a key assumption that transaction fees make up 20% of block rewards following the halving. The team estimates that this cycle's hashprice low will be $35/PH/day.

Then, Galaxy Digital Research modeled infrastructure availability to estimate how much hashrate could conceivably come online during 2024 assuming the previously mentioned hashprice floor. To do this, the team created a sensitivity table for machine replacement, which conveys how much Bitcoin's hashrate would increase if 15 to 50% of all active ASICs were replaced by next-generation models. Then, the team created a capacity expansion sensitivity table to convey how much additional hashrate could come online if 0.5-30 GW of power capacity were to come online in 2024.

After combining all of the analysis, Galaxy estimates that 2-3 GW of additional capacity may come online in 2024, that 25-35% of existing ASICs could be replaced, and that Bitcoin's hashrate may close the year at 675-725 EH/s.

Blockware's Forecast

Bitcoin mining company Blockware provides a number of predictions in its "2024 Market Forecasts" report.

One of these forecasts looks at hashrate growth. Blockware doesn't go into detail about its methodology, but it seems to rely on historical precedent from the 2020 Halving, where hashrate grew by 35% over 2020. Using this as a benchmark, the Blockware research team anticipates that hashrate will have slower growth in 2024 than 2023, but that it will still expand to ~670 EH/s by the end of the year.

CoinShares Forecast

In a report titled "The Halving and its impact on hash rate and miners cost structure," the CoinShares research team also takes a stab at estimating hashrate growth in 2024.

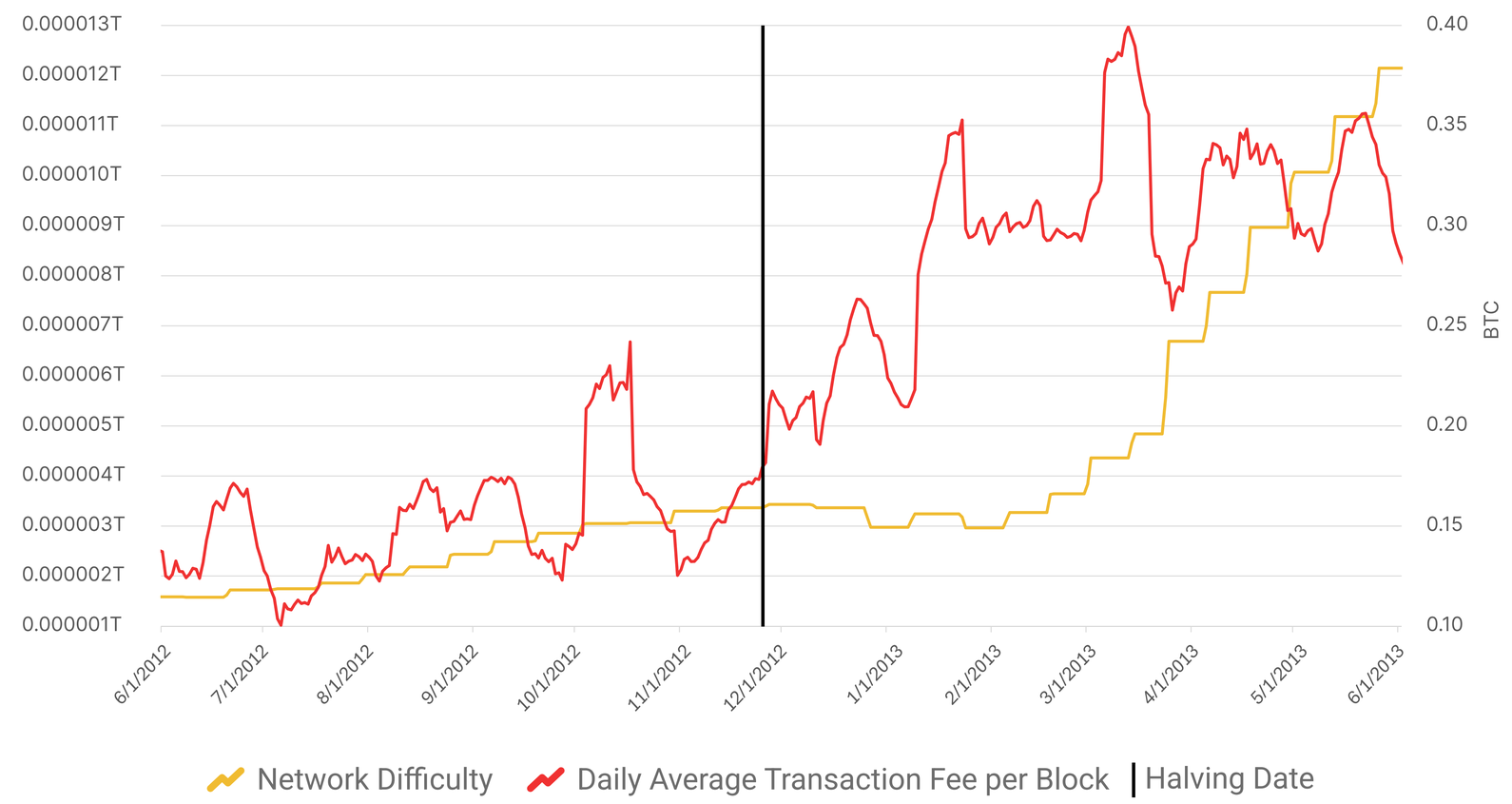
The team uses a combination of historical analysis to look at deviations from the trendline growth of Bitcoin's hashrate as well as out-of-sample data that looks at deviations from this trend. These deviations, the team posits, point to a clear cyclical trend where miners ramp up their hashrate in anticipation of Halvings to stay competitive, which leads to peaks in difficulty before a Halving event that are not sustainable directly afterwards.

As a result, the CoinShares research team arrives at a bearish hashrate target relative to the others covered in this report. The team expects hashrate to dip as low as 410 EH/s 6 months after the April Halving, but they expect it to increase sharply from this 2024 low to 550 EH/s by the end of the year. It's worth noting that the CoinShares team published this report on January 12, 2024, so they made their predictions the farthest out of any of the estimates covered in this report and at a time when hashrate was 517 EH/s.

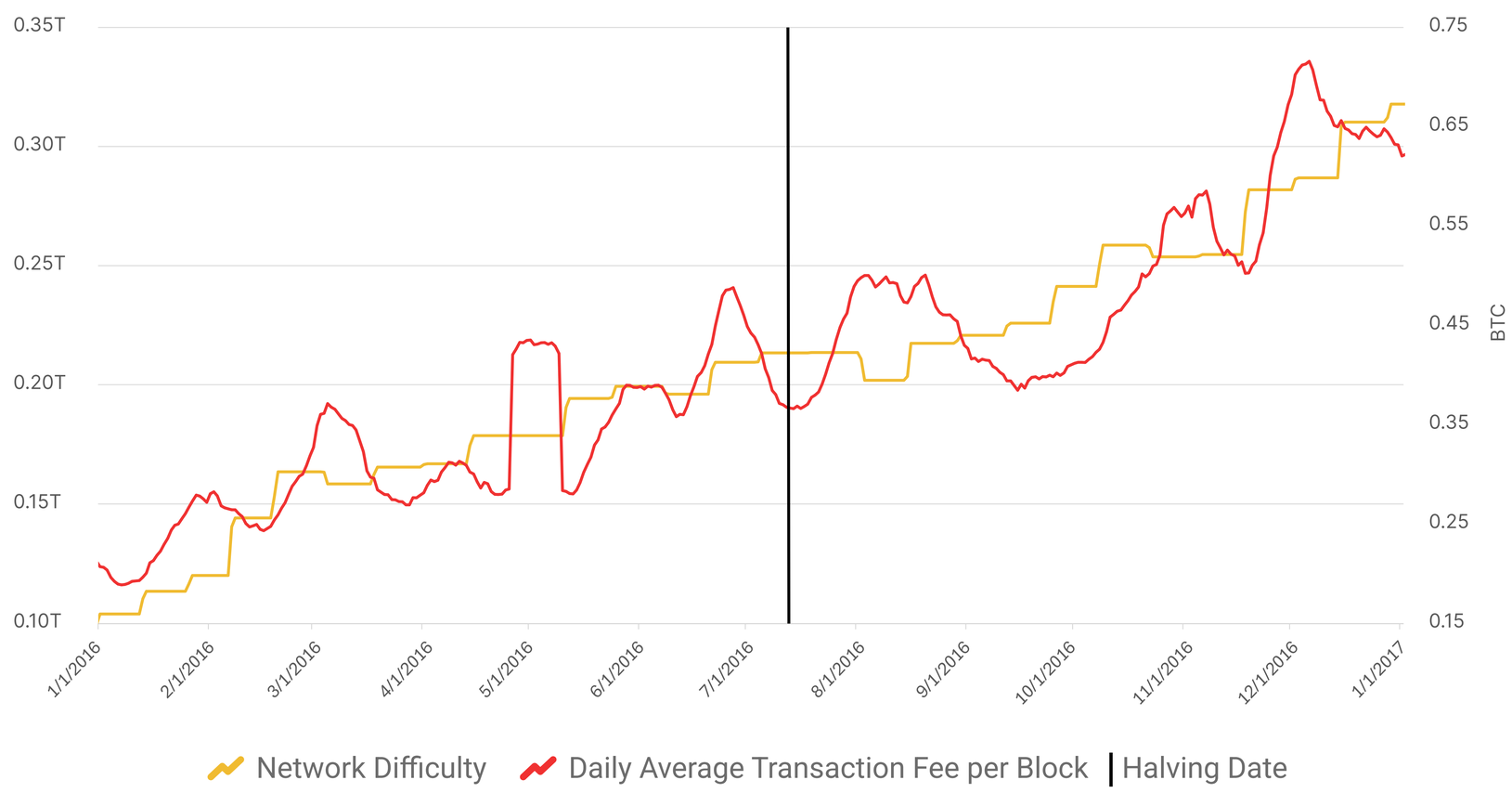
Previous Halvings

While the Bitcoin mining sector and the variables that affect it are markedly different than years past, it can still be useful to observe data from prior Halvings to analyze how the events impacted the Bitcoin network. The three charts below show network difficulty and transaction fees before and after the previous halving. After all three previous halvings, network difficulty bottomed after two negative adjustments following the halving, only to rebound to all-time highs relatively shortly thereafter. Transaction fees only spiked after the 2020 halving.

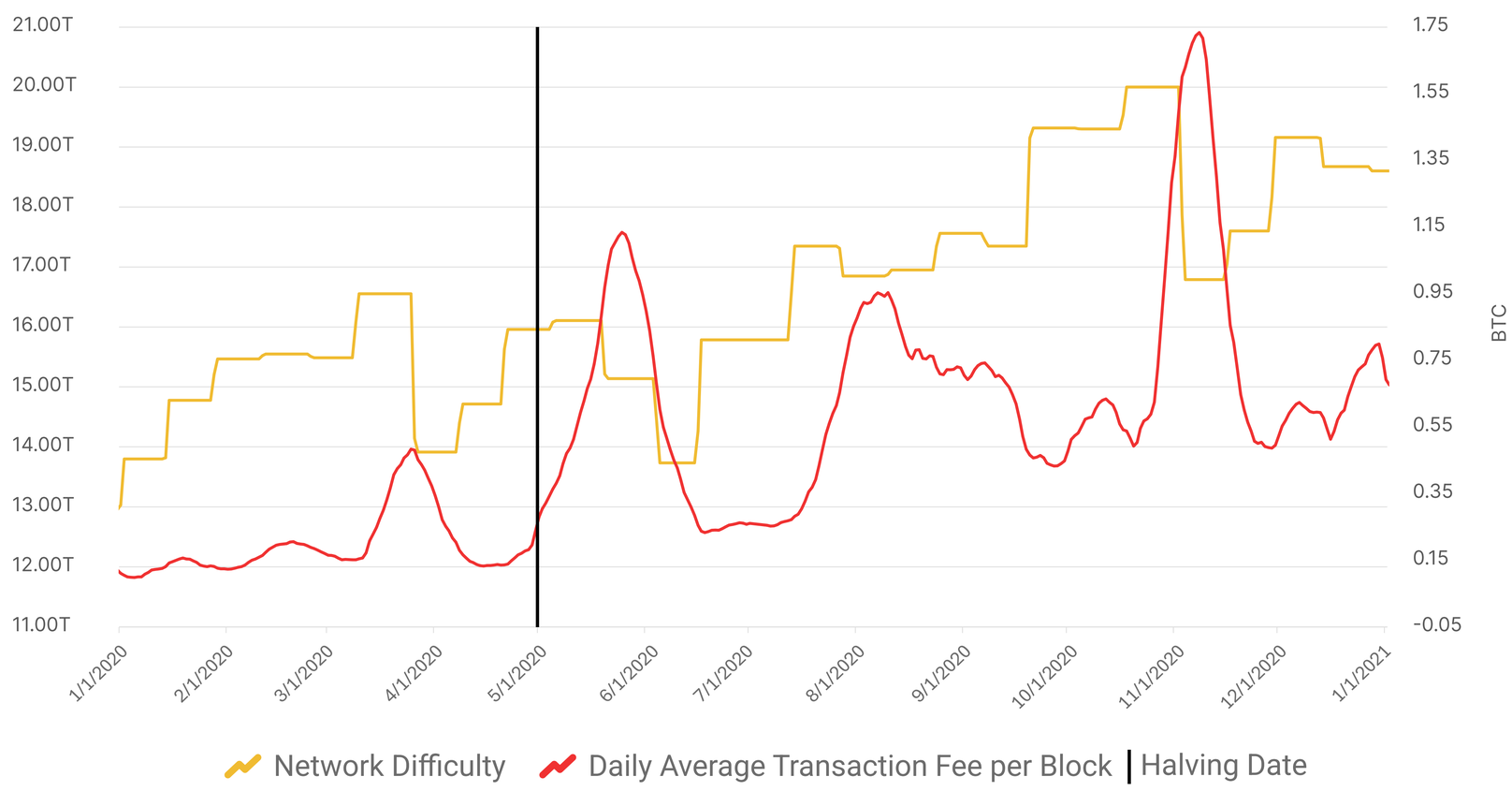
2012 Halving (Nov 28)



2016 Halving (July 9)



2020 Halving (May 1)



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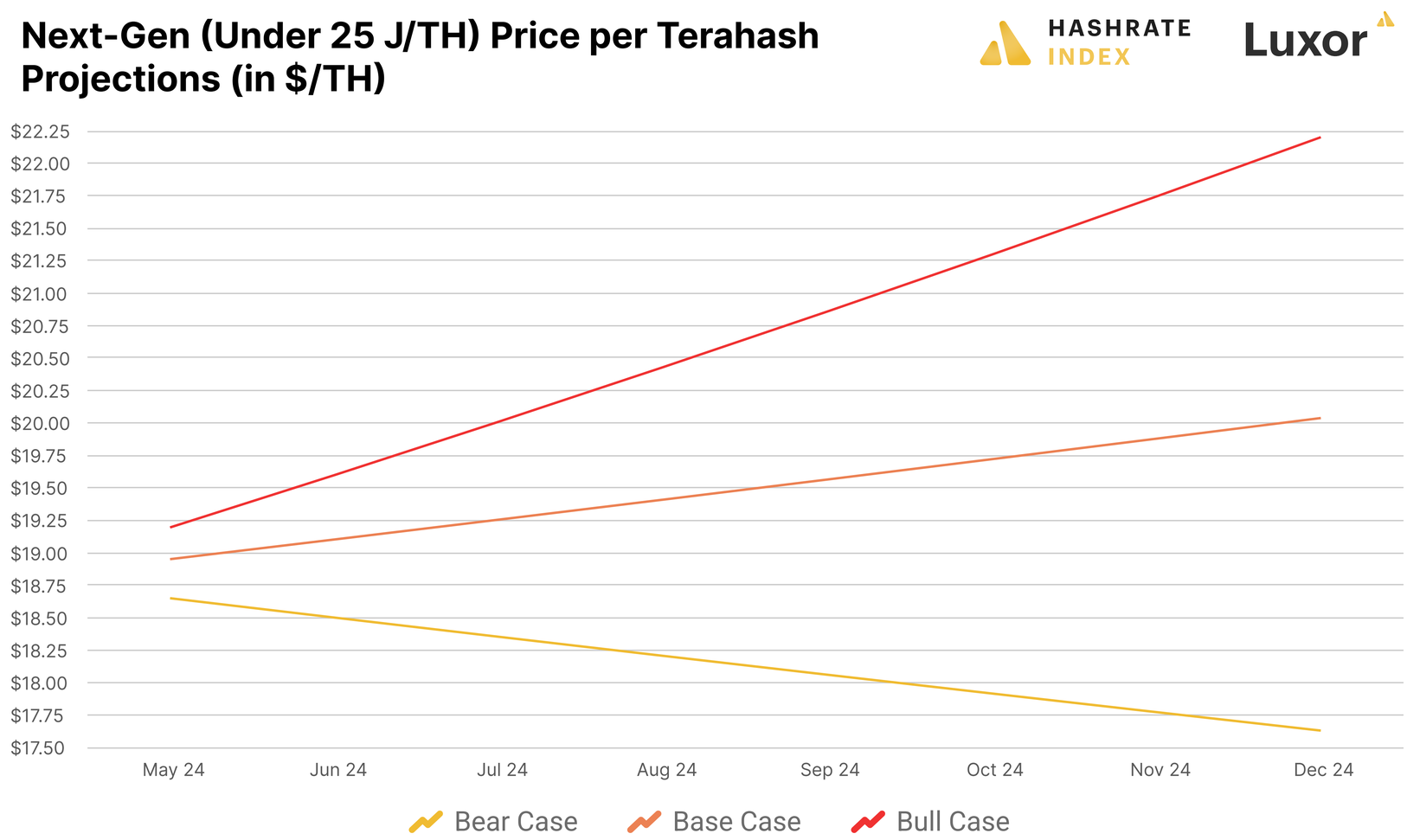
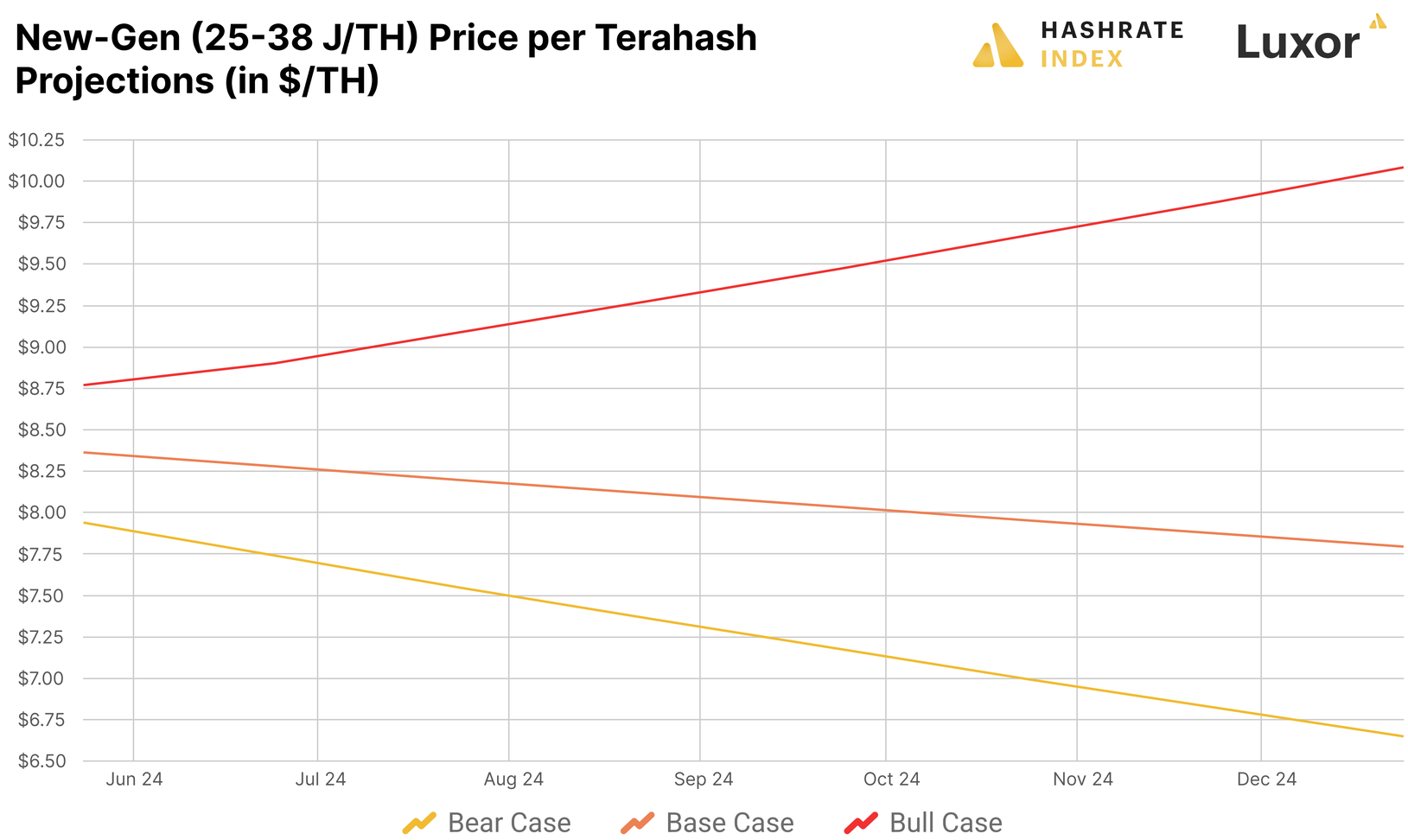
Halving Operational Impacts

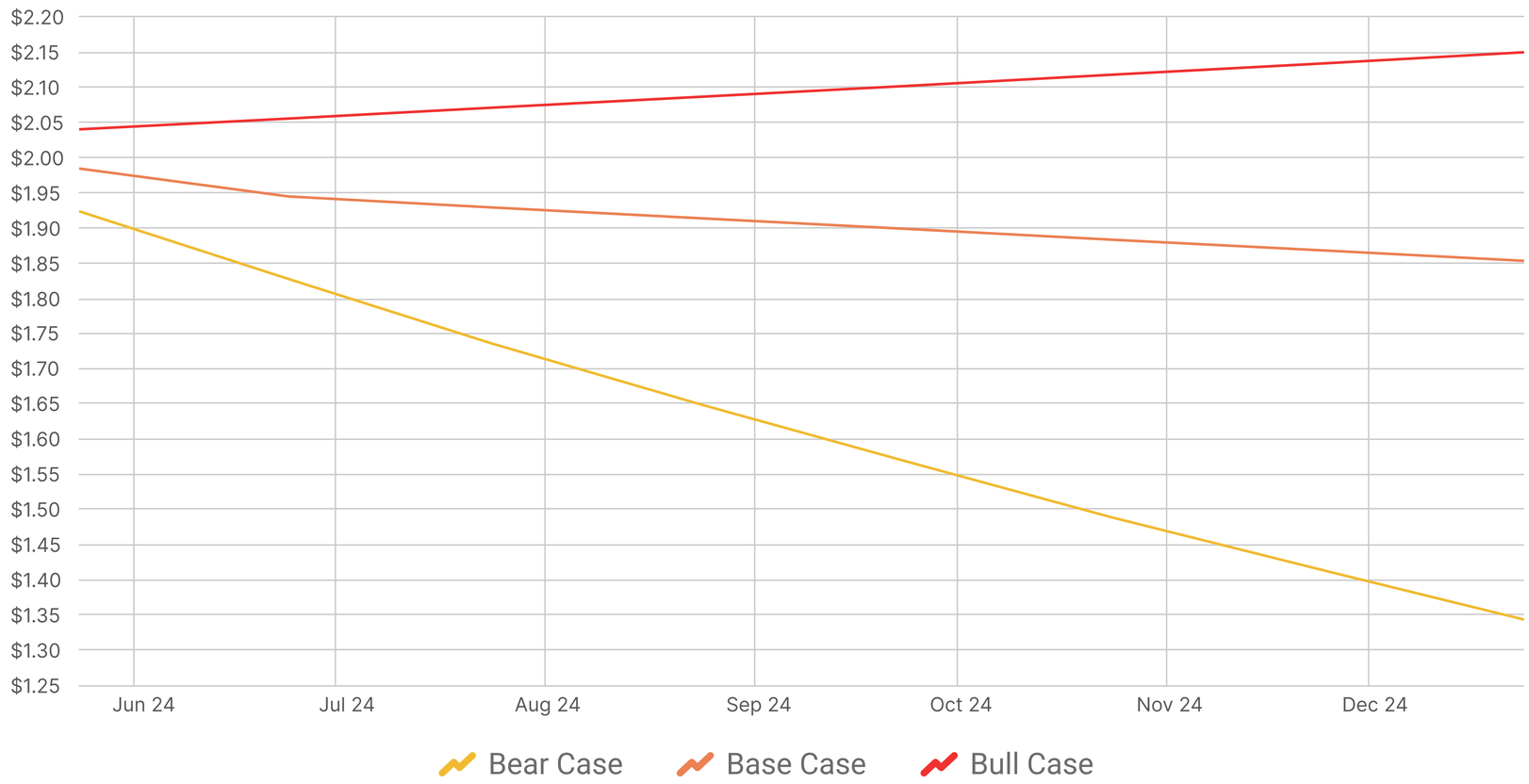
Halving Impact on ASIC Prices

While ASIC prices are determined by supply and demand, they have historically had a high correlation with hashprice. Given that the Halving is a known event that will effectively cut hashprice in half, we would expect ASIC market participants to reprice Bitcoin mining rigs in anticipation of the event.

In the charts below, we project out ASIC prices in terms of dollars per terahash for next-gen, new-gen, and mid-gen ASIC models according to the flat case, base case, bull case, bear case, and stress case from our hashrate, difficulty, and hashprice projection model. To arrive at these figures, we combined our projections with weekly Bitcoin-to-ASIC price ratios from the end of September 2023 through March 15, 2024. We sourced ASIC prices from Luxor ASIC Trading Desk data for the US ASIC market.







It's worth noting that next-generation and mid-generation ASICs could see more dramatic price decreases after the Halving depending on hashprice as these machines flood the market (the obvious historical corollary here is the S9, a model which many miners were giving away for free after the Third Halving). In this case we could see machines trend towards the low $/TH values very quickly.

One final thing to note is that, so long as public miners are trading at a significant premium to their hashrate, they are incentivized to purchase machines despite lower expected returns, which could put positive pressure on ASIC prices after the Halving.

ASIC Breakeven Power Costs

Unless Bitcoin's price sees a substantial increase over 2024, the Halving will drastically lower the breakeven power costs of Bitcoin mining ASICs.

Based on the average of our base case hashprice projection for 2024 and assuming default settings, the breakeven power cost of an M30 would be $0.07/kWh, an S19 would be $0.08/kWh, an M30S+ would be $0.08/kWh, an S19j Pro would be $0.09/kWh, an S19 XP would be $0.12/kWh, an M50S++ would be $0.12/kWh, an M60S would be $0.15/kWh, and an S21 would be $0.16/kWh.

Breakeven Power ($/kWh) per Hashprice ($/PH/day)															
Model	$90	$85	$80	$75	$70	$65	$60	$55	$50	$45	$40	$35	$30	$25	$20
S21 (200 TH/s | 17.5 J/TH)	$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)	$0.203	$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)	$0.196	$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	$0.174	$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)	$0.170	$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)	$0.167	$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)	$0.163	$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)	$0.156	$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)	$0.144	$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/T	$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)	$0.129	$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	$0.127	$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	$0.123	$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)	$0.110	$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)	$0.110	$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)	$0.099	$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)	$0.083	$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)	$0.076	$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

This break even analysis once more highlights that only those miners with next-generation, highly efficient mining rigs and those with low-cost power (or some combination of the two) will retain comfortable margins in the immediate aftermath of the Halving.

Profit / Loss for Public Miners per Hashprice Scenario

Public Bitcoin miners have some of the lowest direct operating costs in the industry, as well as some of the most efficient fleets.

Taking a look at the most recent data available for a handful of these miners, we can derive what their margins may look like after the Halving according to our hashprice scenarios. The table below shows the profit or loss per petahash of computing power by taking an average of post-Halving hashprice from May to December 2024 from our projection scenarios. Please note that this factors in the most recent data on fleet efficiency and each miner's power cost, but it does not include other operational costs such as on-site labor and SG&A; additionally, as with our projections in general, these figures are a simple model that should be treated with caution.

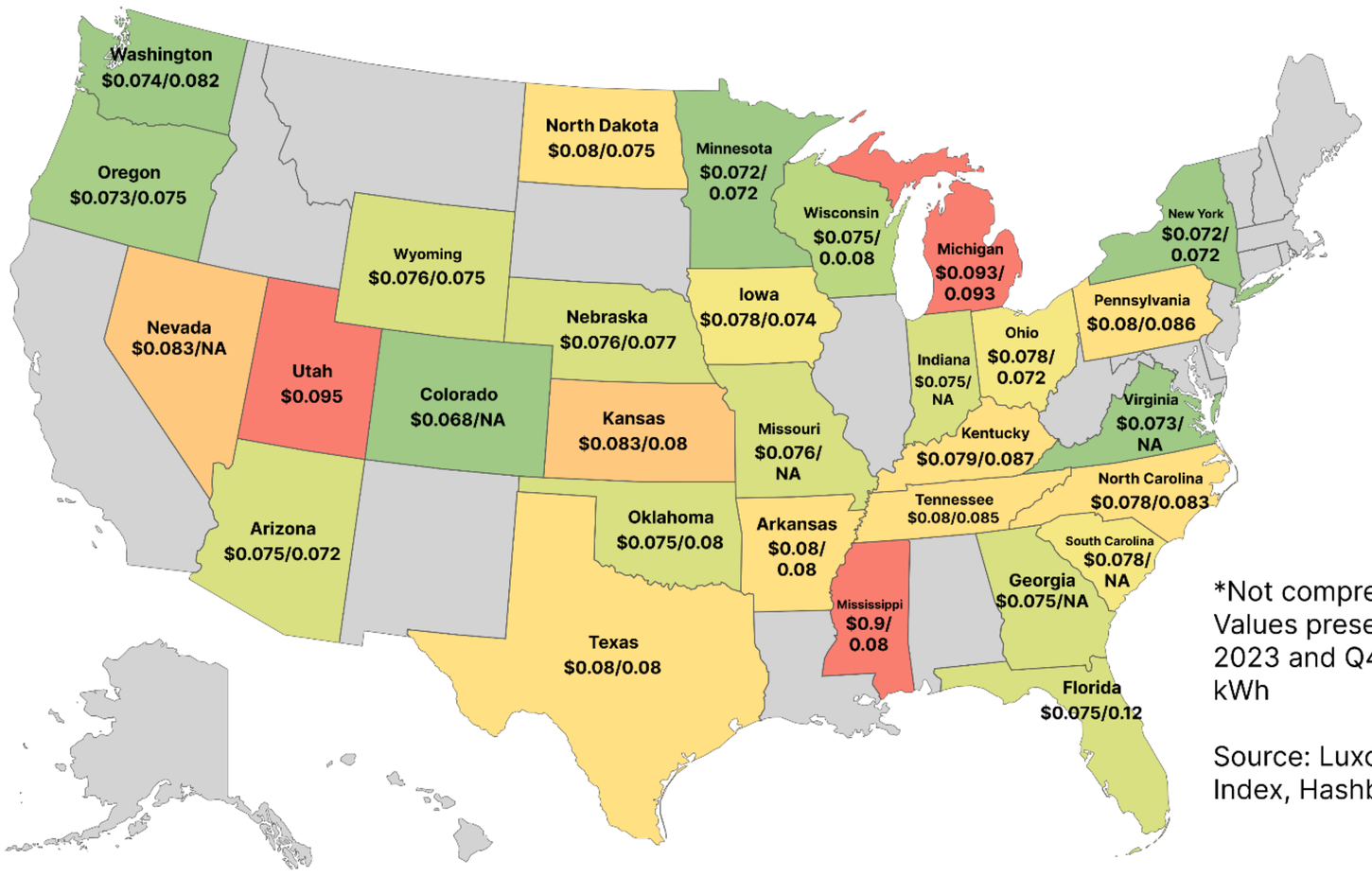
Daily Profit / Loss per PH	Stress	Bear	Flat	Base	Bull	Super Bull
Miner 1	$5.63	$13.78	$26.44	$33.79	$72.32	$106.30
Miner 2	$3.17	$11.33	$23.98	$31.34	$69.87	$103.85
Miner 3	$23.95	$32.10	$44.76	$52.12	$90.64	$124.62
Miner 4	-$7.29	$0.87	$13.52	$20.88	$59.40	$93.38
Miner 5	$18.49	$26.64	$39.30	$46.65	$85.18	$119.16
Miner 6	$1.37	$9.53	$22.18	$29.54	$68.07	$102.05
Miner 7	$18.60	$26.76	$39.41	$46.77	$85.29	$119.27
Miner 8	$13.69	$21.85	$34.50	$41.86	$80.38	$114.37

The model suggests that, even under the stress and bear scenarios, most of the sampled public miners could remain above board. As we will cover in the succeeding sections, these miners could improve their margins further with aftermarket firmware, and they can hedge uncertainty using derivatives such as hashrate forwards and futures.

How the Halving Could Change Power, Hosting Contracts

In 2023, the average all-in hosting rate was $0.078/kWh in the US and $0.072/kWh in Canada, two data points which underscore the fact that miners without next-generation equipment under these rates could become unprofitable (or close to it) after the Halving. In the realm of hosting as a service, hosts may change contracts with their clients, less they lose business as miners become unprofitable after the Halving.

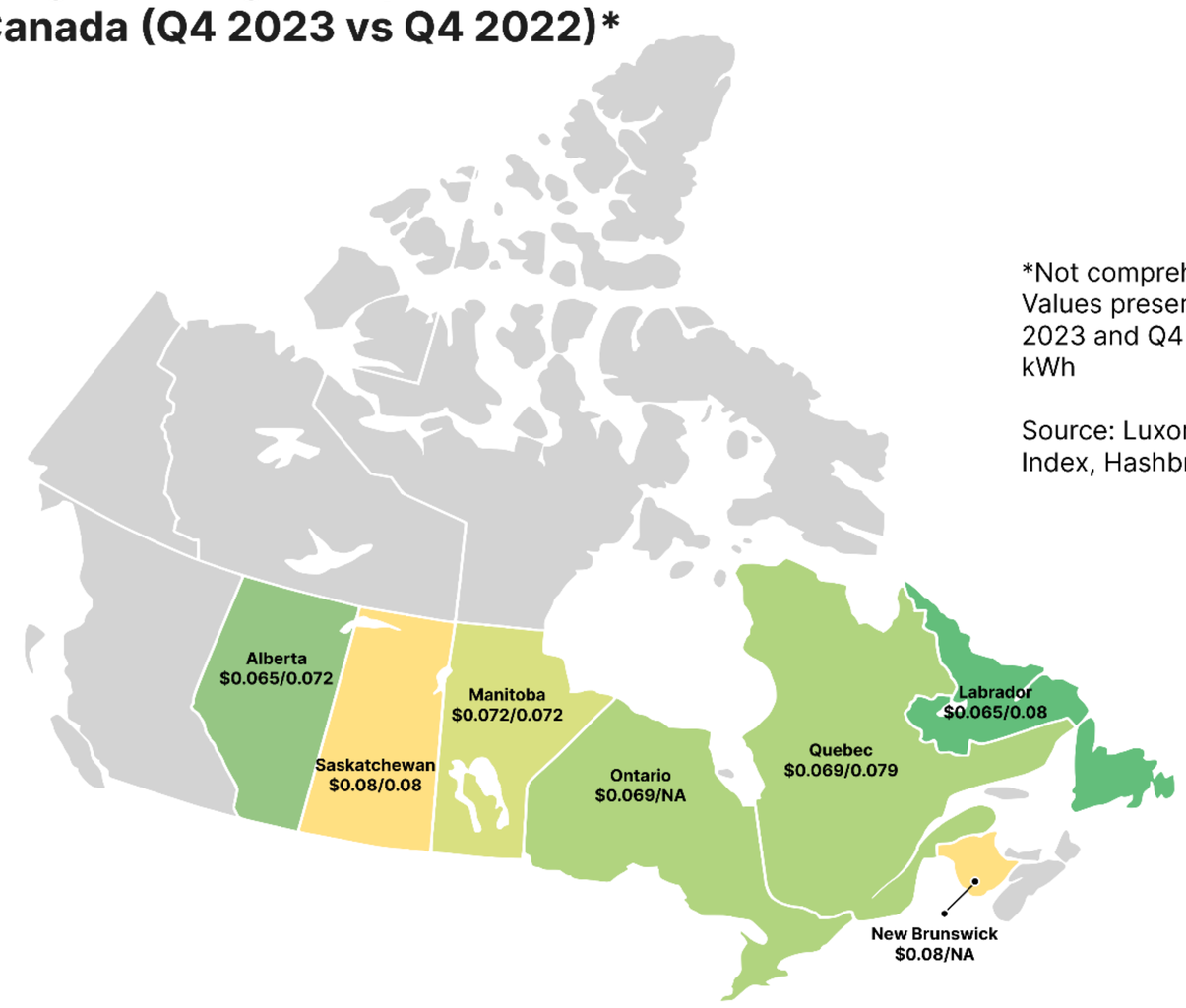
Average Hosting Cost per State in the USA (Q4 2023 vs Q4 2022)*



*Not comprehensive. Values presented as of Q4 2023 and Q4 2022 in $/kWh

Source: Luxor Hosting Index, Hashbranch

Average Hosting Cost per Province in Canada (Q4 2023 vs Q4 2022)*



*Not comprehensive. Values presented as of Q4 2023 and Q4 2022 in $/kWh

Source: Luxor Hosting Index, Hashbranch

Indeed, hosts and clients may increasingly partake in profit sharing arrangements, where hosts grant their clients a lower power cost in exchange for a share of their monthly Bitcoin mining profit (or in some cases, a share of total revenue). We anticipate that profit sharing will become more common in hosting agreements in the US and Canada in 2024 and beyond.

Additionally, some hosts may seize client rigs in accordance with their operating contracts. Essentially, some miners may stop paying their power bills after the halving should they become unprofitable, after which point the hosts may then requisition these machines and operate them for proprietary mining. We expect hosting providers to become large miners this cycle, and have a 1-2 cent kWh buffer before they too become unprofitable.

Ultimately, we expect a shakeup in the hosting market in North America among small-to-mid-sized miners who have failed to upgrade their fleets to next-generation machines like the S19XP and S21 or who have not installed after-market firmware to improve their efficiencies. Larger miners may have more room to negotiate favorable terms and profit shares with their hosts, and so we expect that such miners will likely remain online in the year after the halving.

Hashrate Migration Patterns

As with old-gen models like the S9 after the 2020 Halving, we expect that new-generation machines like the S19 and M30 will migrate to lower-cost areas after the 2024 Halving.

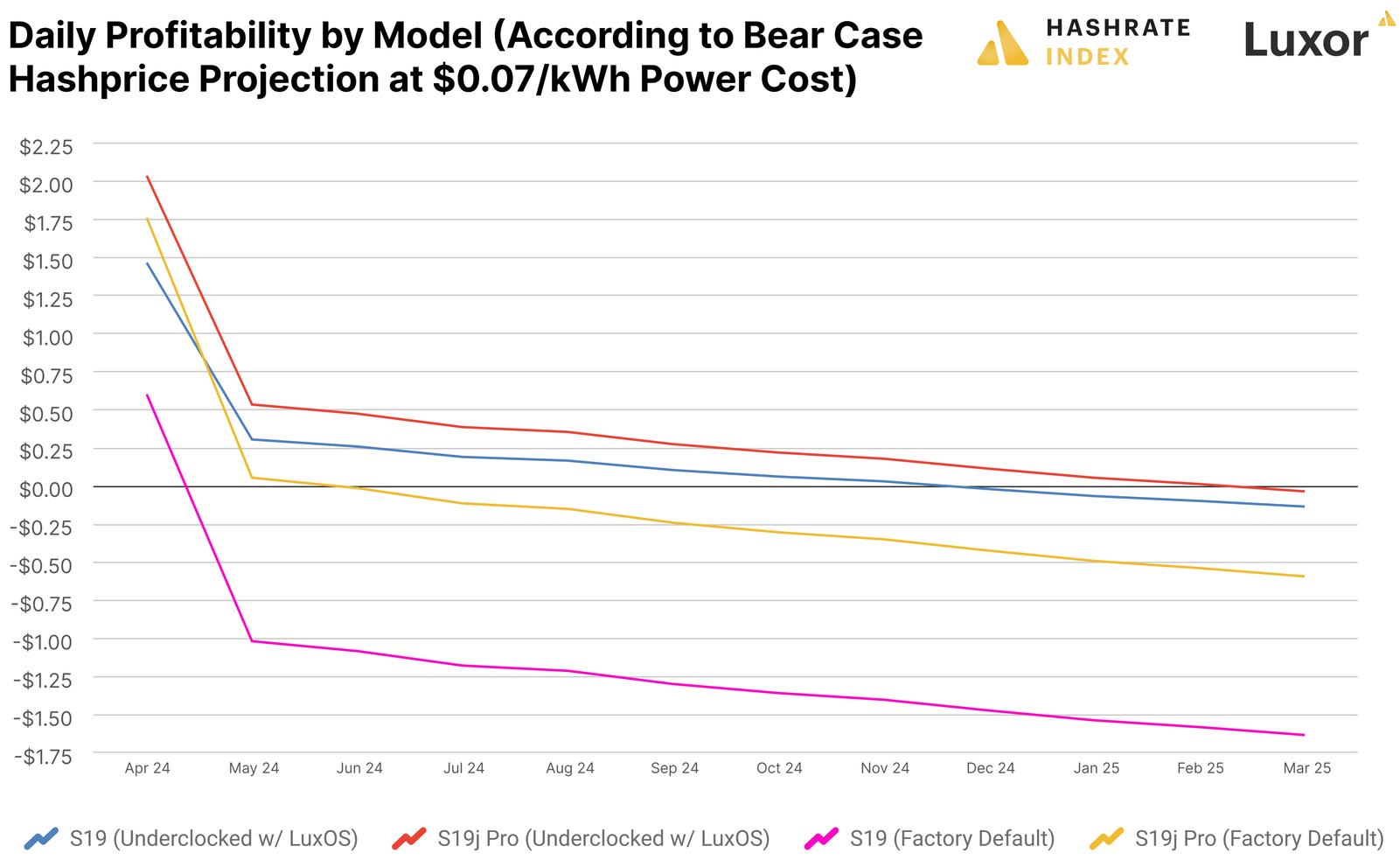
We expect Africa and South America to be the primary beneficiaries of this shift, especially the energy rich countries such as Ethiopia and Paraguay. For its part, the Ethiopian government (via its investment arm) signed a memorandum of understanding in February of this year with a Hong Kong-based Bitcoin mining company to establish a joint-venture Bitcoin mining operation, a development that indicates the promise the region holds for future Bitcoin mining development. We estimate that there are roughly 400 MW and 250 MW of available Bitcoin mining capacity in Africa and South America, respectively.

How Underclocking Firmware Can Improve Mining Margins

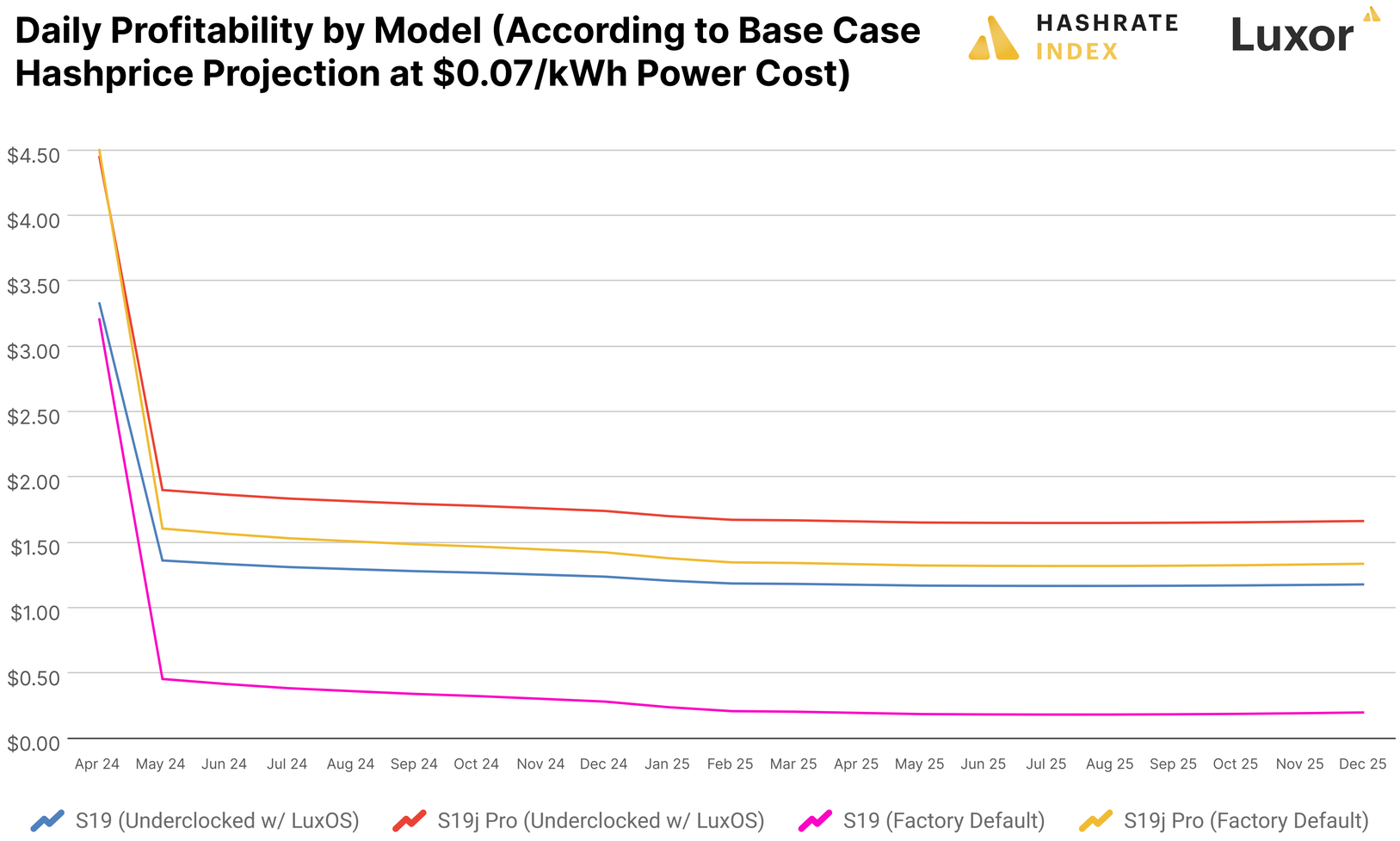
As certain ASICs become unprofitable at higher power costs, sophisticated operators will use custom firmware as a way to improve their fleet efficiency to remain profitable. We saw this occur at scale in 2020 with the S9 model. For new-generation models like the S19 and S19j Pro that are at risk for becoming unprofitable, for example, LuxOS and other custom firmware can improve their power efficiency as much as 27% 15.4% respectively.=

To demonstrate how this can positively impact the operational longevity of these models, we graphed out profitability for the S19 and S19j Pro using our bear case scenario hashprice projection and specifications when underclocking these models with custom firmware versus running the default settings. Under default settings and the bear case scenario, the S19 plummeted into negative margins in May 2024, and the S19j Pro became unprofitable in October 2024.

Custom firmware, though, could extend the operational lifespan of the S19 and S19j Pro by 7 months and 10 months, respectively.



Going further, even under the base case hashprice scenario, where the S19 and S19j Pro aren't rendered unprofitable, LuxOS still boosts their margins by 50% and 11%, respectively.



As the results of the prior hypotheticals suggest, firmware strategies should become a necessary focus for any miner's operational strategy after the Halving. For Bitmain's Antminer S19 series – the most common in the industry – there are four primary custom firmwares in the market.

After-Market Firmware	Domiciled	Released	Firmware Type	Model	SOC 2 Compliant?
ePIC UMC	Canada	2023	Proprietary	Purchase	No
Luxor Firmware	USA	2023	Proprietary	Subscription	Yes
Braiins OS	Czechia	2018	Proprietary	Subscription	No
Vnish.com	Russia	2018	Proprietary	Subscription	No

Source: Luxor Business Data, Public Disclosures

A number of publicly traded companies have announced the use of custom firmware in their press releases and SEC filings, and we anticipate that this number will increase in the coming year as they seek to maximize their fleet efficiencies and revenue. Citations for disclosed firmware use from these public companies is included in the appendix.

Miner	Ticker	Custom Firmware Use	Custom Firmware Provider
CleanSpark Inc	NASDAQ: CLSK	Yes	Undisclosed
HIVE Blockchain Technologies Ltd	HIVE-CV	Yes	Undisclosed
Hut 8 Mining Corp.	HUT-CT	Yes	Undisclosed
Core Scientific	NASDAQ: CORZ	Yes	Proprietary
Iris Energy	NASDAQ: IREN	Yes	Undisclosed
Bitfarms Ltd.	BITF-CV	Yes	Undisclosed
Marathon Digital Holdings Inc	NASDAQ: MARA	Yes	Proprietary
Cathedra Bitcoin Inc	CVE: CBIT	Yes	Vnish (White Label)
Investview	OTCQB: INVU	Yes	Proprietary
Riot Blockchain, Inc.	NASDAQ: RIOT	Undisclosed	Undisclosed
TeraWulf	NASDAQ: WULF	Undisclosed	Undisclosed
Greenidge	NASDAQ: GREE	Undisclosed	Undisclosed
Cipher Mining Inc	NASDAQ: CIFR	Undisclosed	NA
DMG Blockchain Solutions, Inc	DMGI-CV	Undisclosed	NA
Argo Blockchain	ARB.L	NA	NA
Bit Digital Inc.	NASDAQ: BTBT	NA	NA
BIT Mining Ltd	NYSE: BTCM	NA	NA
Northern Data AG	NB2-GY	NA	NA
Galaxy Digital	GLXY.TO	NA	NA
Mawson Infrastructure Group Inc	WIZP:OTCQB	NA	NA
Sphere 3D	NASDAQ: ANY	NA	NA
Stronghold	NASDAQ: SDIG	NA	NA
Applied Blockchain	NASDAQ: APLD	NA	NA
Bitdeer	NASDAQ: BTDR	NA	NA
Soluna Holdings	NASDAQ: SLNH	NA	NA

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 network hashrate to continue its upward trajectory, even in the face of a hashprice decline.

As a benchmark, the current network breakeven hashprice is $37.20 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. 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										
J/TH Improvement	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
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										
J/TH Improvement	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
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										
J/TH Improvement	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
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

Hashrate Markets Can Give Miners a Much-Needed Hedge

We believe that Bitcoin miners will increasingly turn toward native Bitcoin mining hedge instruments after the April 2024 Halving as a way to hedge hashprice volatility and revenue uncertainty. This is the natural evolution of most commodity industries.

Luxor's hashrate forwards and exchange-traded futures offer a solution for miners to hedge against the Halving's revenue shock by allowing them to sell their mining productivity forward. This derivative product essentially enables miners to sell the future production of their mining operations at a predetermined price, thereby providing a way to manage revenue uncertainty in a volatile market environment.

By utilizing hashrate forwards, miners can mitigate the risks associated with fluctuations in Bitcoin's price and network difficulty, both of which directly impact mining profitability. Miners can secure a guaranteed income stream by entering into a forward or futures contract. This strategy allows miners to establish a predictable revenue stream, helping them to cover operational costs, invest in equipment upgrades or expansion plans, and also secure capital.

These derivatives tools provide Bitcoin miners a native hedging instrument because it allows them to hedge their exposure to hashprice, which makes them the perfect complement to bitcoin price futures (which allows miners to hedge the price of the digital commodity they produce) and energy price futures (which allow them to hedge their primary cost).

Traditional commodities producers use derivatives as a tool to hedge their revenues. Currently, however, the majority of of public Bitcoinminers do not hedge their incomes. A handful do, and GSR has compiled a list that details the companies that have announced some form of hedging heading into the halving.

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

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Final Thoughts

What's past is prologue, and every event and consequence that stemmed from Bitcoin's prior Halvings have set the stage for the forthcoming one. That said, past results are not necessarily indicative of future results, so just because previous Halvings produced tempestuous environments for Bitcoin miners, there's no guarantee that the Fourth Halving will wreak similar havoc.

Indeed, as we have indicated in this report, we believe that the next Halving could be an anomaly compared to its predecessors. The current bitcoin bull market and transaction fee activity from inscriptions and ordinals have furnished the opportunity for many miners to stay viable after the block subsidy drops to 3.125 BTC. If Bitcoin's price holds or increases from here, a modest amount of hashrate may come offline. And if the current trend continues, we expect that hashrate will see slow growth over the next year, as compressed margins -- made worse by a slow but steady increase to difficulty -- will limit how much hashrate can come online and stay profitable.

Finally, even though the Halving likely won't disrupt miners to the extent previously imagined, margins will still be very lean after the event. As such, it would behoove miners to improve operational efficiencies in any way they can, either by implementing firmware or upgrading to new ASIC models, as well as hedge their revenues, power price risk, and Bitcoin volatility.

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Appendix

Bitcoin Price

Given the unpredictability of Bitcoin price (and any financial asset price in general) we proposed a range of scenarios based on Bitcoin futures and options markets. At the time of writing, the implied probability distribution for Bitcoin price from Deribit's Bitcoin options market were as follows:

Probability	Apr-24	Dec-24
1%	$30,000	$15,000
10%	$50,000	$38,000
24%	$58,000	$65,000
38%	$64,000	$75,000
Futures Price	**$66,600**	**$73,500**
38%	$73,000	$125,000
24%	$82,000	$180,000
10%	$95,000	$300,000

The Bitcoin price assumptions we use for our modeling (for April 2024-December 2025) were as follows:

Scenario	Bitcoin Price Assumption Range
Super Bull	**$74,526 - $171,661**
Bull	**$69,332-$105,240**
Base	**$66,391 - $78,455**
Flat	**$64,500**
Bear	**$46,997 - $39,768**
Stress	**$31,331 - $26,512**

Transaction Fees

Quantitative Forecasting Techniques

To forecast transaction fees, Luxor has developed a variety of univariate and multivariate forecasting models. On March 2, 2024, Luxor's various transaction fee forecasting models produced the following results.

UNIVAR Models	March	April	May	Quarter (3 months)
ARMA(1,1)	0.33721873	0.33736402	0.33746827	0.33735034
ARMA(1,2)	0.51922911	0.49626589	0.47614974	0.497214913
ARMA(2,2)	0.4898597	0.48408902	0.47206664	0.48200512
Cross-Sec Causal Models	**Signal/Indicator**			
OLS	0.55040347			
Lasso	0.40456269			
Ridge	0.54939968			
Time-Series Causal Models				
VAR(1 Lag)	0.54719397	0.64802339	0.64309637	

A discussion of individual transaction fee forecasting techniques can be found in this Hashrate Index research paper.

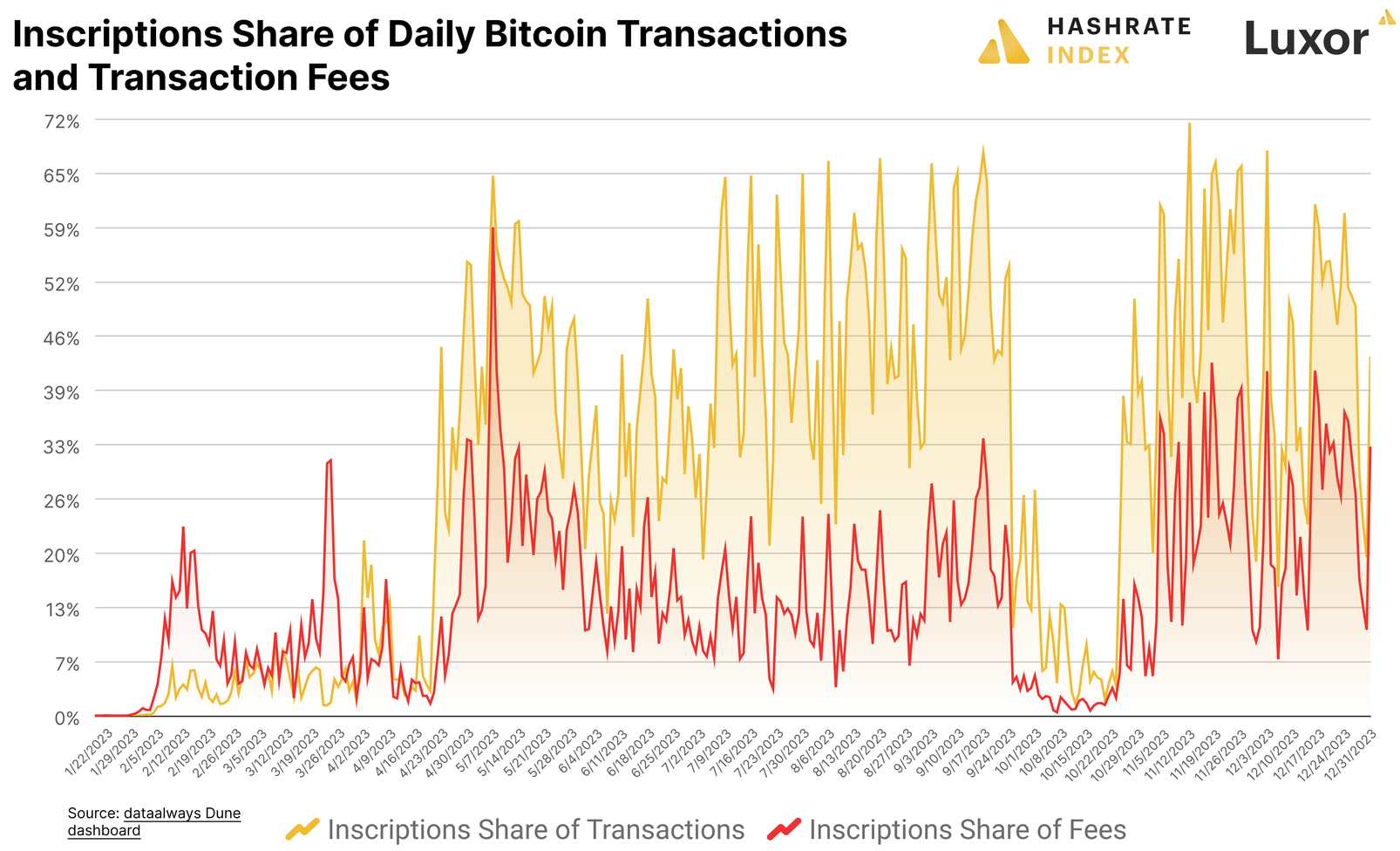
Transaction Fee Scenarios

Based on the analysis above, the transaction fee assumptions we use for our modeling will be as follows:

Scenario	Transaction Fee Assuption
Super Bull	3.13
Bull	2.5
Base	**0.64**
Flat	**0.34**
Bear	0.2
Stress	0.1

Ordinal and Inscription Impact on Transaction Fees

The biggest dark horse for transaction fees (and by extension, hashprice) after the Halving comes in the form of a new technical standard for Bitcoin-based non-fungible tokens (NFTs) and digital collectibles: ordinals and inscriptions. In 2023, the development revived transaction fees as a substantial source of mining revenue, so much so that 2023 was the penultimate year for transaction fee rewards in Bitcoin's history. Last year, miners earned $797,867,915 in transaction fees, 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.



We expect that with the bull market in full swing, 2024 could be another blockbuster year for transaction fee revenue thanks to a new token standard known as "Runes."

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.

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 opcodes, collection creators can create a token parameter with a set supply (for example, the ORDI BRC-20 collection, has a total supply of 21,000,000 and uses ORDI as a ticker). 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. These 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.

In Q2-2024 and beyond, a new inscription design could become the primary driver of transaction fees. So-called Runes, an inscription standard developed by ordinal/inscription creator Casey Rodamor, are text-based inscriptions that are similar to BRC-20 tokens with a few key differences. The technical design distinctions are beyond the scope of this report, but the important detail is that, like BRC-20, Runes will allow anyone to publish minting guidelines on Bitcoin's blockchain for a Runes series, which anyone with the technical ability can use to mint Runes within that series; like BRC-20 tokens, each Rune collection has a specific ticker to identify the collection (for e.g., HASH) and each has a set supply that collectors can mint.

As such, the same minting incentives that exist for BRC-20 tokens will also exist for Runes. Assuming Runes generate enough demand, it's plausible that they will lead to comparable transaction fee volume as May, November, and December of 2023, the three peak months for BRC-20 inscription activity last year. Casey Rodamor plans to launch the first Runes mint on block 840,000 – the block that marks the Fourth Halving and the first one to include the new block subsidy of 3.25 BTC.

Block Subsidy

While the block subsidy is absolutely certain in terms of blocks, it is not certain in terms of time. Therefore, it is important to consider when the halving will occur to fairly judge the future value of hashrate on a specific date(s). In theory, block times should average 10 minutes. In practice, due to luck and many other factors in the short term and Moore's law in the long term, block times can deviate from the 10 minute average. The table below shows average, minimum and maximum average monthly block times over different periods.

Time Period	Avg. Monthly Blocktime	Maximum Avg. Monthly Blocktime	Minimum Avg. Monthly Blocktime
All Time	9:54	5:40	28:33
Since 2017	9:45	8:49	12:11
Since 2018	9:52	9:12	12:11
Since 2019	9:47	9:17	10:19
Since 2020	9:42	9:17	10:01
Since 2021	9:34	9:17	9:52

Firmware Use Citations

- https://investors.cleanspark.com/news/news-details/2024/CleanSpark-Releases-December-2023-Bitcoin-Mining-Update/default.aspx
- https://www.bamsec.com/document-search?entityId=1720424&numVisible=60&query=custom%20firmware&backToACDSView=entities
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