

Tenth CryptoSuper 500 List  
Miners Receive Boost from Price Ramp in 2023 and Higher FeesStephen Perrenod  
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**Note:** This research report is an analysis of the technologies and trends surrounding proof of work cryptocurrencies. It is not, and must not be considered as, financial, investment, or legal advice. Disclosure: As of this date, author has long positions in MicroStrategy, Argo Blockchain, Marathon, and ETF vehicles GBTC and BITO that hold Bitcoin and its futures contracts.

## Proof of Supercomputing

"Money has become information. Bitcoin is energy securely encapsulated as information. Electrons to eternal bits" - @moneyordeb



This is our tenth semi-annual crypto mining report; we have been producing these reports for four and half years. Bitcoin's domination of the list has grown through time. As of the ninth list released in November 2022, Bitcoin was responsible for 90% of the annual economic value of crypto mining production.

Its dominance in market capitalization has grown so much that we are now down to two coins only that make the cut for this list: Bitcoin and Dogecoin. In fact, despite there being 24,000 cryptocurrencies of various types in existence, Bitcoin has 47% of all the market capitalization. It's worth essentially as much as the other 24,000 combined.

Bitcoin has had a good start to 2023, with its price up by 62% since 12/31/2022. Some of this may be due to the banking crisis that has been playing out in the US and Europe.

If a coin does not use proof-of-work (POW), which is true in over 99% of the cases, it is not using large amounts of computing resources. In this series of reports that began in 2018 we are tracking supercomputing levels of usage for cryptocurrency creation and for transaction fees received. Proof-of-stake methods and related Byzantine fault tolerant protocols use variations of voting systems. These systems require only nominal amounts of compute power, with stake holders being significantly more centralized than with decentralized POW methodology.

Many think low usage of compute power for a cryptocurrency is a feature. We see it as a bug. High levels of compute power and the energy to fuel it are a feature for proof of work

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OrionX Constellation™ reports cover 6 Es: big trends (Envision), industry milestones (Events), historical view of a technology segment (Evolution), main vendors in a market segment (Environment), customer decision criteria (Evaluation), and how vendors in a segment score (Excellence) based on the OrionX methodology, which considers market presence and trends, customer needs and readiness, and product capabilities and roadmap.

cryptocurrency, especially Bitcoin, with more than 300 Exahashes/second of computational security.

This is not so very different from when one wants to run the most demanding computational fluid dynamics simulations, for which very high levels of compute power are required, to obtain useful levels of computational accuracy and fidelity. Now substitute security for accuracy and fidelity.

Security comes from high levels of compute power, not low. We are talking about cryptographic protocols that create chains, where every block in the chain becomes *exponentially* stronger as a new block is added in front. High security leads to high value. One stores gold in Fort Knox and underground vaults for a reason.

Bitcoin's block chain is a highly secure vault, and the Nakamoto consensus protocol prevents double spending (or counterfeiting) of tokens. It is non-corruptible.

Those assurances are handed over to committees of humans or even individuals once you move to proof-of-stake. The FTX exchange and its associated 'altcoin' failed last year because of human tampering and greed. A different company's algorithmic stable coin failed because it had little to no actual dollar backing. It was simply a promise, a paper tiger.

### Bit Power

Jason Lowery, a Major in the US Space Force, has recently completed his master's thesis, and published it under the moniker Softwar. It is available on Amazon and will soon be available free in .pdf format from MIT. He says Bitcoin represents "bit power". And as hard power, not as soft power. Hard power, and yet non-lethal.

Lowery thinks it could revolutionize warfare, starting with cyberwar and information warfare. These are especially important to the Space Force and its fleet of satellites.

As I wrote in my review of Softwar on Goodreads:

*"Because Bitcoin is grounded in real world power and custom cryptographic hashing hardware, it has the potential to provide a base security layer for our Internet that is plagued with a broad range of attacks and exploits.*

*Because Bitcoin provides such high security, a non-lethal arms race may develop for hashing power and strategic reserves of Bitcoin.*

*"Consider the email spam problem. What if you demanded people put a stamp on every email they sent you otherwise it would not be opened, that would cut down on your spam. Charge them a few cents in the form of Sats, tiny fractions of a Bitcoin. And unlike stamps, Sats are reusable by the recipient. {n.b. - There are 100 million Sats per Bitcoin}*

*"Imagine you are a company trying to protect secrets, you could add security layers and interfaces that demanded small amounts of Bitcoin."*

Thus, another way to look at Bitcoin is as a repository of hard power, namely electrical power, electrons sent across voltage drops and converted to cryptographically secure bits through a protocol that is deliberately designed to be power-hungry to solve the 'double spending' and Byzantine General's problems. It is designed to maximize the security around the assets it creates, and not to minimize the electrical power consumption.

Those assets are information and can either be monetary or can be other valuable information. Ordinals make it easy to attach documents that can only be accessed with private keys, just as private keys are required to spend Bitcoin located on the decentralized ledger that is replicated in thousands upon thousands of nodes around the world.

Major Lowery is now briefing this thesis widely within DoD and is advising the DARPA Strategic Technologies Office. We may see the Defense Department develop a very different outlook toward Bitcoin than the present views held over at Treasury and the Federal Reserve.

### Mining or Minting

The Bitcoin block reward has two components, a block subsidy reward that is received by the one mining rig (custom ASIC computer) that first solves the cryptographic hash puzzle, and a transaction fee component. The fees are paid by users, rewarding the miner who encodes their transactions on the blockchain, and users bid for space on the chain. It's a winner take all cryptographic lottery for both the subsidy portion and the fees for a particular block.

We can think of the creation of new Bitcoin, which is credited to the miner through the block subsidy, as a minting process. There is no digging underground. New coins are minted with each block. Miners can keep those, which they will do, but typically they will sell the majority of those to offset operating and capital equipment costs. And the fee component is the remainder of the reward. Typically, fees have been small, less than 10% of the total reward, but under certain conditions such as when China banned mining in the middle of 2021, those have increased substantially.

This has happened again recently, due to the new ordinals inscription capability, which allows for NFT and token creation, and which we will discuss later in this report.

The Bitcoin block subsidy reward gets cut in half every four years, in a deliberately disinflationary monetary policy that is coded into the consensus algorithm. The next Halving in early 2024 will cut the reward per block from 6.25 BTC (bitcoins) to 3.125 BTC. Given this reality, at some point, miners would eventually have to receive most of their reward from the transaction component, not the newly minted supply component.

### Energy Usage

Now you may be worrying about Bitcoin's energy usage. How intensive is it, and how green is it? There are several millions of custom ASIC mining rigs located all over the world, and typical energy usage per rig is 3 kiloWatts.

It is true that the energy usage has been growing. In particular, the computational hash rate is up from 220 Exahashes/sec (EH/s) to 350 EH/s in the past year. But the mining rigs are also getting more efficient, with the high-end rigs now producing some 140 Terahashes/sec, up from typically 100 a year ago.

Bitcoin does account for a fraction of a percent of global electricity production. However, it is a small fraction of alternative monetary systems' usage. Gold mining uses more energy, and the finance industry uses a great deal more. One ought to realize that something of value is being created. Bitcoin is a production process, a minting of value process, and the value has been growing rapidly with time, roughly as the fifth power of time (with the age of the Bitcoin block chain). Bitcoin is a circular economy asset, highly reusable.

The total CO2 equivalent production from Bitcoin is about 65 Megatons of CO2 according to one source. However global CO2 released into the atmosphere by human activity is 37 Gigatons, so the contribution is a small fraction

of a percent of all CO2 emission. According to the Bitcoin Mining Council it is only 1.1 part in one thousand, just 1/900 of global CO2 emission.

To focus on Bitcoin, which creates value, is to not focus on making a much larger finance industry or the data center industry more efficient. It is to not focus on fixing the problem at the source, the inputs to electricity generation. Note that the finance industry creates little or nothing, it is a fee-for-service (one can say rent-seeking) industry. Thus, the centralized finance industry, feeling most threatened by Bitcoin as an alternative non-debt based monetary asset and system, has been the severest critic of Bitcoin mining and its energy usage.

### Crypto Mining Rig Efficiencies

Bitcoin mining is a highly competitive arms race for more hash power, and for access to the lowest price electricity. In the table below we show estimated profitability based on 5 cent per kiloWatt-hour electricity. This accounts only for electricity and no other operating or capital costs, so it is a sort of maximal operating revenue.

Mining rigs need to be capitalized over a two- or three-year lifetime, they become non-economic relatively quickly given the rapid growth in total hash rate and in the continued increase in power of individual mining rigs. They can cost as much as the electricity input over their lifetimes. Global aggregate hash rate has doubled from about 170 Exahashes/sec to 340 Exahashes/sec just since December 2021.

Manufacturer	Model	Hashrate Terahash/s	Electricity Watts	Efficiency = Joules/Terahash	Operating Revenue per day at 5 cents kWh, BTC \$27.6K
Bitmain	Antminer S19 XP Hydro (immersion cooling)	255	5304	20.8	US\$19.16
	Antminer S19 XP	140	3010	21.5	US\$10.40
	Antminer S19 Pro	110	3250	29.5	US\$7.11
	Antminer S19	95	3250	34.2	US\$5.61
MicroBT	Whatsminer M53	212	5500	25.9	US\$14.62
	Whatsminer M50S	126	3276	26.0	US\$8.68

*Table 1. Some popular Bitcoin mining rig parameters of hash rate, electricity consumption, and power consumed per hash rate delivered (lower is better). Operating revenue after electricity costs only is calculated using 5 cents per kWh. According to [hashrateindex.com](https://hashrateindex.com) pricing is in the range of \$16 to \$24 per Terahash/sec for these machines, with higher prices commanded for better efficiency scores.*

Since the network hash rate is around 350 Exahashes/sec one can say there is the functional equivalent of about 3.2 million S19 Pro mining rigs active currently. Of course, there are many older machines still active depending on the Bitcoin price, so the number is probably closer to 5 million reasonably powerful systems actively mining.

The current generation of mining rigs is dominated by 5 nm ASIC technology from Chinese suppliers. Intel entered the field and then dropped out in April in a cost-cutting move. Block has said it is going to build systems based on open-source designs; they have announced a 5 nm prototype. They also have a follow-on 3 nm system development project underway. There have been reports since 2022 of a 3 nm ASIC development at Samsung.

Since we have been in the 5 nm era since 2021, later this year or into 2024 would be a natural timeframe for the first 3 nm systems.

## Regulation

To a significant degree, Bitcoin mining's critics have been winning the public opinion battle. Bitcoin mining was largely banned in China, although there still appears to be a lot of under-the-table mining. However, Bitcoin is highly anti-fragile and since it is just code and electrical power and in principle runs on any type of computer, it can't really be banned in a global sense. The decentralized ledger resides on over 10,000 modest-sized "full node" systems around the world. These hold the ledger and can easily re-validate transactions, but not commit transactions, and can be general purpose computers or even just Raspberry Pi systems.

What governments can do is restrict access to, or control prices, of the electricity inputs. In Kazakhstan, which for a while was the #2 location, the electricity usage grew substantially and restrictions and taxes on electricity usage were imposed.

And now in the US, the White House has even proposed a 30% surtax on Bitcoin mining's electricity usage. Thus, if a miner thought they were paying 5 cents on average in a favorable location, instead they would effectively have to pay 6.5 cents per kWh, cutting significantly into their margins, or eliminating profitability all together.

Naturally, these measures, if adopted, just drive Bitcoin mining to other locations. The White House proposal seems unlikely to pass in the current Congress.

The failure of FTX and other cryptocurrency scams or bankruptcies that occurred during 2022 have created a difficult climate of perception for Bitcoin as well, even though Bitcoin itself does not suffer from the centralized nature of alt-coins or of exchanges. Bitcoin has no CEO, no marketing department, and is not a Ponzi scheme, as was FTX essentially, in which new entrants are paid from prior investors' funds.

In fact, Bitcoin as an asset, is safer in principle than large bank deposits, as we have seen with recent bank runs, provided one holds the private keys oneself. There are also multi-party custody solutions, similar to a safety deposit box. A recent poll showed half of Americans are worried about the safety of their bank deposits, despite FDIC insurance coverage to \$250,000 per account.

## Geographic Locations

The map below from Visual Capitalist shows the average electric input cost to mine Bitcoin on a per country basis. Total cost is dominated by electricity and the cost of the ASIC mining rigs. One sees that the lowest electricity costs are found in North America, Scandinavia, Central Asia, the Middle East and a few locations in South America and Africa. So, mining tends to congregate in these regions. While this map is from August of last year and the cost increases when the global hash rate increases (it's a competitive lottery!), or when the price of electricity increases, the overall relative position for different countries does not change that much from year to year.

Miners seek out the lowest cost electricity, and that is typically from hydropower, stranded natural gas, and low-cost coal or nuclear or geothermal sources, along with wind and solar power. Overall, the consumed mix is more than 1/2 from renewables (including nuclear), which is substantially greener than electricity energy input sources on average.

Several years ago, China had 2/3 of the global mining capacity for Bitcoin, much of it derived from hydroelectric power, but also low-cost coal-fired electricity generation. After China banned Bitcoin mining in mid-2021 some *sub-rosa* mining has remained, but the United States was the biggest destination and growth area for mining hash rate. Since then, the US has occupied the #1 position with as much as 40% of the global hash rate.



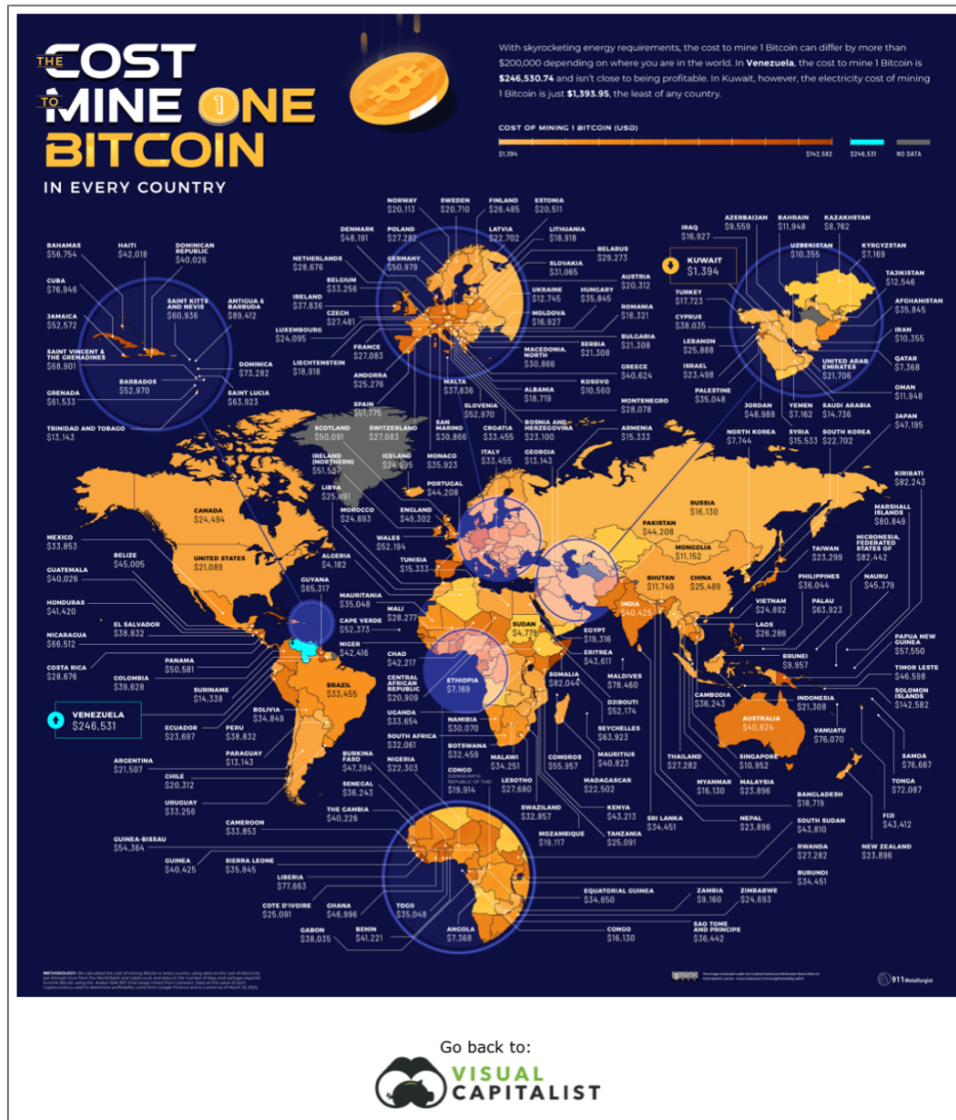


Figure 1. Visual Capitalist map of electricity input mining cost for one Bitcoin, average price for each country.

The US together with Canada has nearly half of the world's hash rate, and a large portion of this has been fueled by venture capital funding. Publicly traded companies are now responsible for close to 20% of the global hash rate.

The details of the geographic distribution are a bit murky because Chinese mining was not completely shut down. It may be as high as 20% of the global hash rate. There is presumably under the table mining continuing, in undetectable locations or with local party bosses looking the other way in exchange for "tea money".







The previous go-to data source for geographic distribution data was the Cambridge Centre for Alternative Finance, but they have not updated their map since January 2022.

In addition to the US, Canada, and China, Russia and Kazakhstan have substantial hash rate, some of which is due to relocation of mining farms after the Chinese ban. These five countries appear to be responsible for some 75 to 80% of Bitcoin mining's hash rate.

### Top Six Minted Coins

Table 2 below lists the top six proof-of-work coins by market capitalization. We also show the hash rate and annual production along with the current and maximum capped supply that will ever be available. Bitcoin's annual economic value production is 25 times as large as #2 Dogecoin.

Prior to our last report, Ethereum was the #2 coin for production, and it remains the #2 among all coins for market capitalization. But in September 2022 it dropped proof of work in favor of proof of stake. This has decreased security and increased centralization. Ethereum uses a validator scheme that requires ownership of a minimum of 32 Ethereum to be able to validate transaction blocks.

Icon	Coin	Symbol	Market Cap (B\$)	Total hash rate	Annual production \$B (nominal)	Current Supply (millions)	Max Supply (millions)
	Bitcoin	BTC	517	354 EH/s	8.80	19.37	21
	Dogecoin	DOGE	10.0	635 TH/s	0.38	139, 282	No cap
	Litecoin	LTC	5.84	703 TH/s	0.21	72.88	84
	Monero	XMR	2.79	2.45 GH/s	0.02	18.28	No cap
	Ethereum Classic	ETC	2.54	128 TH/s	0.11	141	211
	Bitcoin Cash	BCH	2.20	0.65 EH/s	0.06	19.39	21

*Table 2. The Top 6 coins by annual production value. We list the market cap and price and aggregate hash rate, as of 5/14/2023. In addition, we list the current supply and maximum supply allowed. Only Bitcoin (BTC) is well into the Exahash domain. Hash rates for other coins are not directly comparable since different coins use different hashing algorithms. Only Bitcoin has an annual production value over \$1 billion, and apart from Bitcoin, only Dogecoin produces over \$300 million per year. Only Bitcoin and Dogecoin pools make our cutoff of \$38 million.*

### Transactions Fees, Ordinals, BRC-20 Tokens

The block reward for each block of approximately 10 minutes of Bitcoin transactions is composed of a fixed amount, the block subsidy, and a variable amount of fees. The block subsidy is new Bitcoin awarded to the winning miner, and at present is 6.25 BTC per block. This will drop to 3.125 BTC with the next halving, Bitcoin's fourth, expected to occur during April 2024.

The other portion is transaction fees paid by users, and as recently as a month ago, the fees were only a few dollars per transaction and the fee component of the total block reward was just a few percent.

However, there are new capabilities on the Bitcoin blockchain known as Ordinals and along with the SegWit and Taproot enhancements this allows all types of data to be more conveniently stored on the main chain. The Ordinals are numbering schemes that allow a single Sat to be identified out of the total 2.1 quadrillion Sats that will ever exist.

A new standard BRC-20 is now proposed that is similar in some ways to Ethereum's ERC-20 that has been used to create a large number of new cryptocurrency tokens. Unlike ERC-20, BRC-20 does not provide full support for smart contracts, although Bitcoin itself does have some support for smart contract creation. By May 9th, the market cap across new BRC-20 tokens had exceeded \$1 billion.

Already, and mostly during the single month of May, over 6 million Ordinal 'inscriptions' have been created on the Bitcoin block chain. This has increased demand for block space by an order of magnitude and driven up the fees by an order of magnitude as well. For one week in early May miners collected \$62 million in fees alone.

Up until March when BRC-20 was introduced, fees had been running \$1 or \$2 per transaction, now as of May 10 they are averaging \$20. In some ways this is reminiscent of the high fees in 2017 during the block size wars that saw Bitcoin Cash and BSV hard fork away from Bitcoin. Note that since then fees have generally been low and that both BCH and BSV failed to gain significant following. Bitcoin Cash is now worth less than 0.4% of Bitcoin.

What is strange is that many people are minting tokens by making minimal value transactions of less than 1000 Sats, a fraction of a dollar, and end up paying much more in fees than the value of the Bitcoin in the transaction. They are hoping to sell the tokens or digital art created and recover their fees and more in the future.

Perhaps we are entering a higher fee regime but that is good for miner profitability, which suffered greatly during the 'crypto winter' in 2022. There were at least five blocks in the past few days for which the transaction fees exceeded the subsidy! We expect things to settle down some but maybe fees will remain in the \$10 area give or take a factor of two.

For our tabulation we take the average of the prior 31 days, and in this case transaction fees add 12.6% on top of the block subsidy for miners' revenue. This will be volatile going forward but so is the Bitcoin price.

Eventually miners will have to earn most of their income from fees in any case, since the block subsidy of new Bitcoin halves and halves and halves again every four years.

These higher fees are not an existential problem, since very much lower transaction fees are available on the second-layer Lightning network and other side chain and second layer solutions for Bitcoin. There are ways to buy coffee, one can just use Lightning.



### Publicly Traded Bitcoin Mining Companies

Company	Market Cap \$Million	Pretax Income 2022, \$M	Stock Price \$	Hash Rate plans in Exahashes/sec	Bitcoin Held	Daily Bitcoin mined
Argo Blockchain	72	-186	1.44	2.5, adding 0.3	N/A	4.8
Bitfarms	274	-256	1.13	5.0	465	12.6
Cipher Mining	556	-37	2.24	6, adding 1.2	427	13.5
Clean Spark	394	-40	5.05	6.7	313	17.5
Core Scientific	134	-2163	0.36	14.8	Filed bankruptcy in 12/2022	37.5
Hive Blockchain	273	82	3.25	1.9, adding 2	2,372	9.1
Hut8 Mining	413	-233	1.87	2.6	9,265	4.4
Iris Energy Ltd.	227	-417	4.13	5.5	1,398	10.6
Marathon Digital	1674	-709	10.09	14, adding 4	11,568	23.4
Northern Data AG	429	336	17.27	3.8, adding 0.9	N/A	7
Riot Blockchain	2190	-521	12.59	10.5	7,112	21.3
Stronghold	43	-195	0.94	3.2, adding 0.8	N/A	5
<b>Total</b>	<b>6679</b>	<b>-4339</b>		<b>Up to 85 by Q3 2023</b>	<b>32,920</b>	<b>166.7</b>

*Table 3. A dozen of the largest public companies in the Bitcoin mining space. Although they have collective market cap of over \$6 billion, their pretax income for 2022 was negative \$4 billion due to a difficult price environment for Bitcoin 2022. The market caps are now higher than in our last report, because of the substantial recovery in Bitcoin price during the first months of 2023. The 167 daily Bitcoin mined across these 12 companies represents an 18.6% share of the nominal 900 generated per day. Collectively the companies hold over \$900 million of treasury Bitcoin. Snapshot as of May 10, 2023.*

Mining has rapidly shifted toward publicly traded companies, mostly venture capital funded startups. Most of their mining facilities are in the US and Canada, as well as in Scandinavia. There are expansion plans into the Mideast, Abu Dhabi in particular. Collectively the top 12 companies are approaching 20% of all Bitcoin production and around 1/2 of North American Bitcoin production.

Bitcoin was in a bear market in 2022 and publicly traded mining companies suffered. An ETF that tracks the miners lost over 80% of its value during the year. Many of the companies had to sell much of their treasury

Bitcoin, or some of their equipment. They had to take on debt, issue new stock, and cut back on expansion plans. There was at least one bankruptcy, Core Scientific, who continue to operate.

However, the price of Bitcoin jumped considerably in Q1 of 2023 and despite some pullback is still up over 60% year-to-date. Market capitalization for most of the publicly traded companies is now higher than it was for our Ninth report. The outlook has considerably improved, and higher transaction fee revenues are an unexpected plus.

### Top Mining Pools

Mining pools are not mining farms. They are not hash rate generators per se, although they may have associated crypto mining businesses. One presumes that the earliest pools that were mainly based in China had business relations with Chinese mining farms.

Pool	Country	Bitcoin AEV (\$M)	Dogecoin AEV (\$M)	Total \$M
Foundry Digital	USA	3029	0	1,813
AntPool	Global	2256	54	1,345
F2Pool	Global	1187	68	1,209
Binance pool	USA	994	0	831
ViaBTC	Germany	849	134	838
Marapool	N/A	366	0	515
BTCdotcom	Global	186	0	361
Braiins	Global	179	0	261
SBI Crypto	Japan	97	0	193
Poolin	USA	69	0	149
BTC M4	N/A	55	0	98
Litecoin Pool	Global	0	38	
Top 12 operators		9,266	295	9,561
All Mining		9,866	373	10,239

*Table 4. Top mining pools by value, using Bitcoin and Dogecoin prices as of 5/14/2023. Transaction fees add 12.6% (last 31 days averaged) on top of the block subsidy reward for Bitcoin of 6.25 BTC per block. We only include pools with at least \$38 million revenue for either Bitcoin or Dogecoin. We have seen substantial consolidation, as a result of Ethereum dropping out of the race, and the industry maturation process. Note that these 15 pools (12 operators) account for 93% of the value of Bitcoin and Dogecoin minted (mined). The numbers for Bitcoin are higher than in Table 2 because of significant transaction fee revenue.*

But the pools themselves are brokers for hash rate. Individuals and companies from all over the world will direct their hash rate to pools for convenience and predictability of rewards. In a pool the Bitcoin earned by the pool are shared across all the mining rigs directed to the pool, in proportion to their contributed hash rate. In exchange the pool collects a fee in the range of 1% to 4% of the reward.

In the first few years of reports, we only had access to pool data, but now with the rise of publicly traded crypto mining companies we can report on the progress of those companies as well as the competition between the major pools. Table 4 lists the latest annualized production rates of the 15 largest pools (12 operators).

### Trends

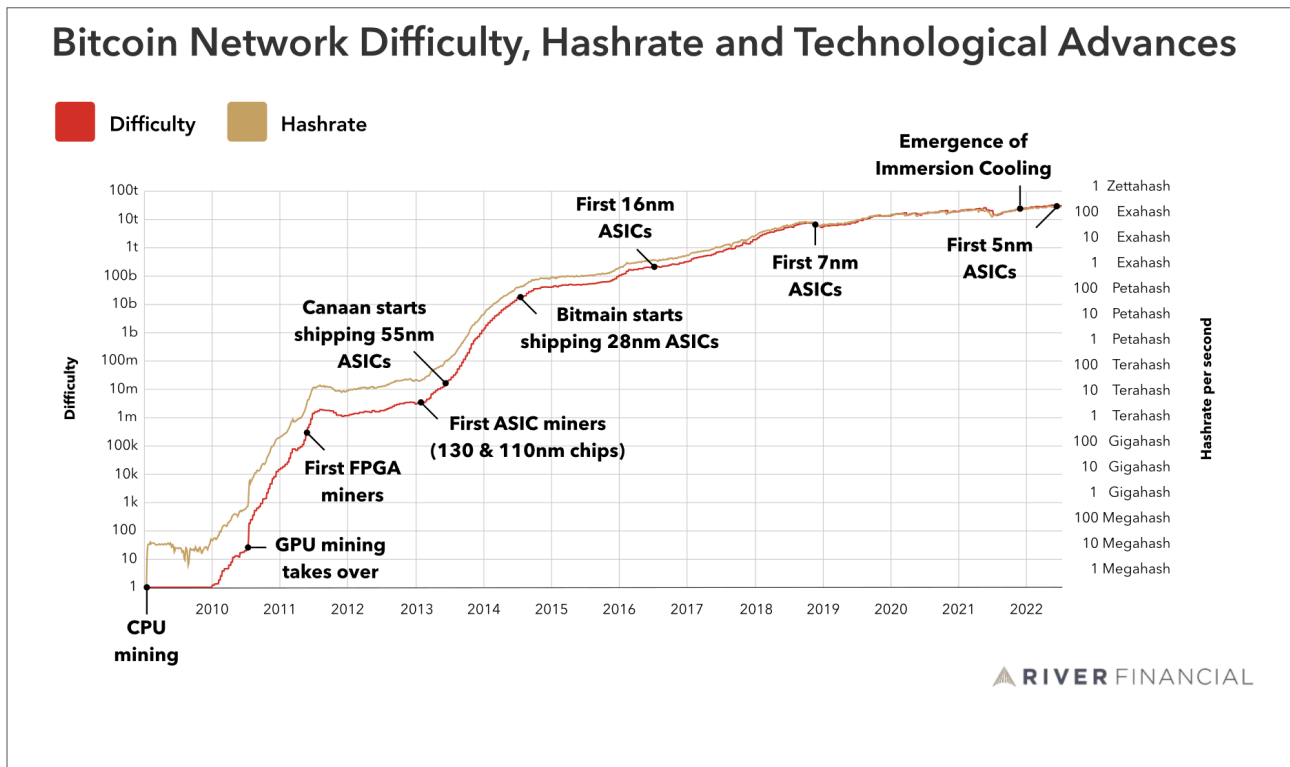


Figure 2. River Financial chart of Bitcoin mining rig history. GPU mining took over from CPUs in 2010, ASIC miners began to dominate from 2013. The current generation uses 5nm technology ASICs and immersion cooling is becoming popular for improved efficiency. The total hash rate has climbed from 1 Megahash/sec to hundreds of Exahashes/sec through these innovations and growing machine count in the Bitcoin mining industry.

Major trends include strong hash rate growth. We are mostly through the Exa era and could enter the Zetta era in the next three or four years. This will be accompanied with greater efficiency of mining rigs, including greater use of immersive cooling, and a growing share of green electrical input.

After an extremely rapid rise in its first nine years, since our first report in late 2018 the computational power, measured in Bitcoin hashing rate, has grown by a factor of 7. Bitcoin minting is an embarrassingly parallel problem distributed across a decentralized global supercomputer with of order 5 million nodes, collectively realizing over 300 Exahash calculations per second. Bitcoin is poised to enter the Zettahash era within three or four years, on current trend of 50% compound annual growth in hash rate.

Bitcoin price strength could continue the next couple of years since we are just about a year before the fourth Halving and the years prior to and after halving events tend to be favorable for price.

Ordinals and BRC-20 tokens are boosting miner profitability by bringing fees back up to the 10% plus range of the total block reward. We are probably in a new era of higher fees, but the level of BRC-20 activity this month, with fees on occasion about as high as the block subsidy, seems faddish and it should settle down somewhat. Nevertheless, this is promising for the long-term profitability of miners.

We will continue to see more regulatory restrictions but also more clarity on crypto generally including exchanges and altcoins, as well as on the electricity availability and cost for miners. All the attention around crypto frauds has caused governments to accelerate their central bank digital currency plans. The European Central Bank seems like they are ready to take the next steps with developing a CBDC for the Euro this year, and the Federal Reserve and Treasury are talking about it more than ever.

### Summary

We began this series of crypto super reports four and a half years ago to understand the intersection of cryptocurrencies and supercomputing. What we have observed during this interval is the increasing dominance of Bitcoin in terms of both the computing power utilized and the associated market capitalization.

Now we have a dozen pools brokering most of \$10 billion worth of annual economic value, almost all from Bitcoin, and with about \$1 billion of that in transaction fees while 90% is due to the value of new coinage.

There have been as many as eight proof-of-work coins that made the cut for our reports, and now as of this report and the prior one we are down to two. Ethereum walked off the field when it moved to proof-of-stake and drastically reduced and centralized its security. Bitcoin started out with 75% of the market cap for top mining pools and now is responsible for 96% of revenue to top crypto miners.

Bitcoin is the ultimate bit power asset, that converts electrons moving across voltage drops into highly secure bits cryptographically stamped into and linked in an exponentially hardened chain. Each block added at the end of the chain increases the security of all prior blocks of transactions. This makes the block chain a highly secure data repository and it makes Bitcoin a natural currency for cybersecurity.

The other great movement has been the rise of the US as the #1 geography for Bitcoin minting during the past two years. China has abandoned its former dominance of the industry as it seeks to promote a central bank digital currency alternative. The rise of the US as #1 has been driven by substantial venture capital investment, such that about half of the North American hash rate is found within publicly traded companies.



## Glossary

**Bitcoin** – The original cryptocurrency, blockchain and consensus algorithm was outlined in October 2008 in the Satoshi white paper. The Bitcoin blockchain began in January 2009. Bitcoin uses proof of work and has a disinflationary monetary policy based on Halvings.

**Blockchain** – A chain of transaction blocks with each block linked to the one prior and the one after by a hashing technique. Each block incorporates a hashed representation of the prior block along with its own transaction records. A specific type of database with time stamped and linked record blocks.

**Block reward** – The reward for being the winning miner of a block. It consists of a subsidy and any transaction fees collected by miners.

**Block years** – A block year is one quarter of a four-year Halving era of 210,000 blocks; block years have 52,500 blocks. They are close to a calendar year in duration, within a week or two. Over 14 block years have elapsed since Bitcoin began.

**BTC** – Abbreviation for the Bitcoin cryptocurrency.

**Cryptocurrency** – A currency stored in a digital ledger that implements cryptographic security to prevent theft or counterfeiting. Cryptocurrencies may be created with different mechanisms and the ledgers are often decentralized to varying degrees.

**DeFi** –Decentralized Finance. DeFi implements automated financial methods by use of cryptocurrencies and blockchains.

**Dogecoin** – A cryptocurrency created from Litecoin, itself a clone of Bitcoin, in 2013, as a joke. It has a mildly disinflationary monetary policy, but unlike Bitcoin, has no limit on the total supply.

**ETH** – The native cryptocurrency of the Ethereum network.

**Ethereum** – The second largest cryptocurrency by market value was created in 2015 by Vitalik Buterin, Joe Lubin and others. It was designed to implement smart contracts such as those used in DeFi. It shifted fully to proof of stake in September 2022, eliminating proof of work mining.

**Halvings** – The algorithmically enforced decrease in the block reward subsidy for Bitcoin miners. Originally this was 50 BTC for the winning block. Halvings occur roughly four years apart after each interval of 210,000 blocks. The last halving in May 2020 dropped the subsidy from 12.5 to 6.25 bitcoins per block, the next will be around April 2024.

**Hash rate** – The rate at which a computer system (mining rig) can generate hash guesses to solve the cryptographic puzzle. A Terahash/s is a trillion hashes per second, a Petahash/s is a quadrillion, and an Exahash/s is a quintillion ( $10^{18}$ ) hashes per second.

**Lightning** – Lightning is a second layer solution for Bitcoin that allows for speedy payments including for very small amounts at very low cost. Lightning channels are opened between parties, and this forms a network. Lightning payments are eventually resolved back onto the first level blockchain in batched transactions.

**Miners** – The computer systems that solve the cryptographic puzzle for a proof of work cryptocurrency. Miners are characterized by hash rate, the amount of solution power. Custom ASICs or GPUs are employed, typically. The first computer that solves the puzzle commits the block of transactions and receives the block reward. Miners are minters of cryptocurrency, through the combination of electricity, cryptographic hashing cycles, and a proof of work lottery reward system.

**Minting** – Bitcoin and other proof of work coins are in fact minted, not mined. Nothing is dug up, and new coins are minted with each block according to the consensus algorithm which in effect enacts a monetary policy.

**Money** – A medium of exchange, store of value, and unit of account. Bitcoin represents monetary technology; it has not achieved full 'moneyness' but is on the path as utility grows. Ethereum removed proof of work and that makes it less 'money' and more of a payments and decentralized finance solution. Bitcoin is now legal tender alongside existing currencies as money in the countries of El Salvador and the Central African Republic.

**Pools** – Pools aggregate hash rate from mining farms plus smaller miners, that choose to contribute their hash power into a collective pool, to gain a proportionate share of the pool's mining rewards. Pools are essentially brokerages, run by companies for a fee share of the Bitcoin processed. They are not themselves mining operations, although they may have associated mining farm businesses.



**Proof of Stake** – In proof of stake, rewards or dividends are paid, in proportional to their share, to existing holders of a coin or token, who have governance and block validator privileges. Holding such a token is conceptually similar to holding a share of a company. Long term value depends on scarcity and utility, but security is much lower than with proof of work.

**Proof of Work** – In proof of work, a cryptographic lottery must be won by miners competing with their hash power. The winning miner validates the transactions for a particular block and receives a block reward that includes a subsidy of new coins and transaction fees. Monetary policy is set by changing the block subsidy on a schedule, and a difficulty adjustment keeps block times around the nominal target. Proof of work and storage on a decentralized ledger with many copies solves the double spending (of the same coin) and counterfeiting problems.

**Reusable Proof of Work** - Hal Finney created the last key technological improvement required for Bitcoin, with a concept for making proof of work tokens reusable. This means they can be spent repeatedly by their new owners, like a coin, rather than used once, like a postage stamp.

**Smart contract** – An automated contract for exchange of value implementing agreed upon rules between the parties for transfers.

**Time Chain** – See blockchain. Blockchains are chains of time-stamped transactions, laid out as a permanent temporal record of those transactions.

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