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Blockchain

Fourth CryptoSuper 500 List: Post Third Halving

Block Reward Drop Presents New Challenges

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Note: This paper is an analysis of the technologies and trends surrounding blockchain and cryptocurrencies. It is not, and must not be considered as, financial, investment, or legal advice.

Evolution

Bitcoin as Global Money

> *"Money has become information. Bitcoin is energy securely encapsulated as information. Electrons to eternal bits. Money in the Internet, and only in the Internet." @moneyordebt*

This new form of money can be transferred across the globe at low cost in a matter of minutes. One Bitcoin has the value of 265 barrels of oil, up by a hundred barrels since the last list in November 2019. Bitcoin and other Proof of Work (PoW) cryptocurrencies are created in a compute-intensive mining process.

> *"Electricity has replaced oil as the life blood of productivity." – Bill Tai*

The value of one hundred million barrels of oil is being produced per annum as new Bitcoins, with electricity as the primary input into specialized cryptomining servers ("rigs").

Cryptocurrrency mining is a specialized form of supercomputing. It relies on large clusters of mining rigs with substantial power and cooling requirements, and the operators of these seek out low cost power and cooling locations. Hydropower access is especially favored, and it has been estimated that some 75% or so of power used in crypto mining by large compute farms is from renewable sources.

Crypto Mining Rigs

The critical parameters for a PoW crypto mining rig are its rate of hash generation and its power consumption. The hash generation rate determines how many attempts a rig can make at solving the cryptographic puzzle required to commit a block to the blockchain. Solving this puzzle provides the first-to-solve miner with the right to commit the block of transactions and received that block's reward. The reward consists of a mining subsidy and fees associated with transactions.

The electrical consumption of a mining rig is usually the dominant contributor to the cost of mining, and the capital acquisition cost is usually the second largest component.

The current block subsidy for Bitcoin has just been reduced from 12.5 Bitcoins per block to 6.25 Bitcoins, as of May 11, 2020. This is baked into the Nakamoto consensus algorithm that cuts the subsidy in half approximately every four years (after each 210,000 blocks of 10

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minutes' average duration). This provides Bitcoin and other cryptocurrencies with similar algorithms with deliberately disinflationary monetary policies, by design.

Table 1 below provides an overview of current top 10 Bitcoin mining rigs. These are the top 10 miners for the SHA-256 algorithm, in terms of their ability to rapidly generate guesses toward a successful solution of a cryptographic puzzle, rated in Terahashes/sec performance (TH/s). These are the latest and greatest for the most part. The arms race obsoletes mining rigs very quickly, within a couple of years or less. All of these are ASIC-based, designed specifically to solve the SHA-256 algorithm. ASICs have replaced GPUs for the vast majority of cryptocurrency mining for over 5 years now.

There are four brands represented; all are from Chinese manufacturers. The Antminer from Bitmain is the leading brand, followed by the Whatsminer systems. Also represented are the Nano Pro and Tardis brands.

One can see that the peak TH/s rate is of order 100. Just to show the scale of this, the current total hashing rate on the Bitcoin blockchain is right around 100 Exahashes per second. Therefore, the fastest machines are about one-millionth of that, and thus we determine that there are a few million crypto mining rigs active around the world.

The machines typically consume around 3 kiloWatts of power. Access to cheap electricity is extremely important for a rig to be profitable. One can calculate a figure of merit TH/s per kiloWatt as shown in the fourth column of the table.

In the last two columns of the table we show the gross margin as a function of power costs assuming 5 cent power prices or 1 cent power. Unless you can get 5 cents or less as your power cost you should probably find another business besides Bitcoin mining. You may find other cryptocurrencies that you can mine economically at higher power charges. Usually the cheapest power one can find globally is about 3 cents. One cent power is unheard of, until recently.

There is a new mining operation in west Texas that has access to 2.5 cent power because of very cheap energy prices currently and access to flared natural gas. Furthermore, they have executed a load leveling agreement with the power authority stating that they will shut down crypto mining during peak load periods. This gives them credits back on their power bill, and the net result is that their power may be as cheap as 1 cent after credits.

An older rig that consumes too much power such as the Tardis listed in the table is headed for the scrap heap, unless you can move it to an even cheaper power cost location.

These are gross operating margins, and one has to subtract other operating costs including cooling, facilities, and administrative costs. And beyond that, every day mining gets harder, because of increased competition and difficulty adjustments. In Bitcoin's case, difficulty increases (decreases) every two weeks (2016 blocks) in proportion to the global collective hashrate that is deployed. It almost always increases since more and faster rigs are continually being deployed. And your rig that once had one-millionth of all the Bitcoin hashing power, in a year may have only 50% of that proportion.

And you have to earn sufficient rewards to recover the upfront capital cost of the mining rig, priced like an entry-level server, perhaps $2000 to $3000. Since each rig has less than one-millionth of the power of the entire Bitcoin mining network, one must have a large number of machines to have a chance of earning block rewards. Alternatively, with one or a few machines you can commit their hashpower to a mining pool, and earn a proportion share of all the rewards from the pool.

We look at the challenging economics of mining in more detail in this article: https://medium.com/the-capital/the-brutal-efficiency-of-crypto-mining-far-beyond-moores-law-92fa90e617e0

Table 1: Some Bitcoin mining rigs (SHA-256 PoW)

Mining Rig	TH/s	Watts	TH/s per KW	Gross Margin, $/day, 5c per kWh	Gross Margin, $/day, 1c per KWh
Antminer S19 Pro	110	3250	33.8	6.22	9.27
Antminer S19	95	3250	29.2	4.84	7.90
Whatsminer M30S	86	3268	26.3	3.99	7.07
8 Nano Pro	76	4000	19.0	2.19	5.98
Antminer S17+	73	2920	25.0	3.21	5.97
Tardis	80	6300	12.7	-0.24	5.80
Whatsminer M31S	70	3220	21.7	2.58	5.62
Whatsminer M20S	68	3360	20.2	2.23	5.41
Antminer S17e	64	2880	22.2	2.43	5.26
Antminer T17+	64	3200	20.0	2.36	5.08

Review of Prior CryptoSuper List (Nov. 2019)

Our CryptoSuper lists are created twice as year; previous lists were released in November 2018, June 2019 and November 2019.

There are now over 5500 cryptocurrencies. Most are worth relatively little, and only 17 have market caps over $1 billion. Market cap is the number of coins or tokens outstanding times the price. In an extreme illustration of the Pareto principle, two-thirds of the market cap of all cryptocurrencies combined is with Bitcoin, the premier crypto.

There are different ways of creating new cryptos, different consensus algorithms or methods of solving the Byzantine generals' problem of preventing fraudulent transactions, e.g. double spending, a form of counterfeiting. The two most robust consensus algorithms from the security and value perspective are Proof of Work and Proof of Stake. But only Proof of Work is a computationally intensive process that leads to *supercomputing* levels of resources being assigned.

We consider here only the most valuable Proof of Work coins, the eight most valuable by total market cap; these are summarized in Table 2. We list the type of hardware required (ASICs in all cases but one), the algorithm, the target block time and subsidy and thus how many coins are 'minted' per day on average. And we list the total hash rate as of May 31. Because algorithms vary so widely, and the value and popularity of even the top coins varies significantly, hashrates range over many orders of magnitude, from the Gigascale range up to the Exascale range.

Bitcoin Cash and Bitcoin SV are hard forks away from the core Bitcoin blockchain. Only Bitcoin, Bitcoin Cash, and Bitcoin SV have hashrates that enter into the Exa domain.

One difference from traditional supercomputing installations is that these are mining pools, and they often welcome anyone to contribute their own compute resources from anywhere in the world, and share in the crypto mining rewards. The problem is inherently embarrassingly parallel since one must make billions or trillions of guesses at a 'nonce' before computing the winning result. However, given the need for extremely cost-effective

electricity it is becoming more difficult for many independent miners who have access only to electricity at typical residential rates.

Table 2: Top 10 Mined Coins (5/31/20 snapshot)

Coin	HW	Algorithm	Block time	Block subsidy	New coins / day	Hash rate	units
Bitcoin	ASIC	SHA256	10 min.	6.25	900	114.50	Exa
Ethereum	ASIC	Ethash	15 sec.	2	11,520	190.70	Tera
Bitcoin Cash	ASIC	SHA256	10 min.	6.25	900	2.63	Exa
LTC	ASIC	Scrypt	2.5 min.	12.5	7200	261.00	Tera
Bitcoin SV	ASIC	SHA256	10 min.	6.25	900	1.66	Exa
Monero	GPU	CryptoNight	2 min.	2.15	1548	1.40	Giga
Ethereum Classic	ASIC	Ethash	15 sec.	4	23,040	8.65	Tera
Zcash	ASIC	Equihash	1.25 min.	5	5760	5.66	Giga

Because cryptocurrency mining is inherently a highly decentralized process, there is also an increasing trend toward operators locating major crypto mining resources in several countries, creating global pools. China has tightened up on some operators, rationing their access to electric power, and this has encouraged migration of resources to Central Asia, Europe and North America.

BTC.com was the top mining pool on the third list, and once again Chinese miners were at the top. The second and third largest countries by cryptocurrency produced value are the US and Hong Kong. We note again, these are pools, so what we are tracking are the host locations. The annual economic value produced by the top pools was $7.4 billion on the prior list.

The Fourth CryptoSuper List, Released in Conjunction with ISC

The information for this fourth edition of the CryptoSuper 500 list was collated the final two days of May 2020 and during the first week of June 2020. Prices for the top mined coins were taken on May 31. The block production and hashrate numbers are monthly totals in the case of Bitcoin and Bitcoin Cash. Weekly hashrate averages were used for the other six top mined coins.

For this list, across all the eight coins, the cutoff for a mining pool to be in the Top 50 was annual economic value of at least $9.5 million per year, including mining rewards and transaction fees.

Global Hashrate: Ten to the 20th Power

Hashes in crypto mining are the metric that parallels flops in the supercomputing world. But hashrates are much higher due to many repetitions of a small cryptographic problem attacked with custom ASICs.

Crypto miners compete via Proof of Work consensus algorithms in order to win a block reward (subsidy and fees) and commit a group of transactions to the blockchain. Cryptocurrency mining via Proof of Work continues to represent the most effective class of consensus algorithm to maximize security in a decentralized manner, and it allows coins to accrue significant value. They are scarce because they are costly to produce and because maximum supply is algorithmically constrained.

In our CryptoSuper 500 race, we only look at the top mined coins that use Proof of Work, since these are the *only supercomputer class workloads* in the cryptocurrency world. Other consensus algorithms are much less costly, but as the marketplace has consistently demonstrated, other consensus methods impart much less value and security to a cryptocurrency. This is a trade-off between store of value and utility attributes.

Crypto mining entered the Exascale era in 2016; four years ago, the global hash rate for Bitcoin was already exceeding an Exahash per second. As of this writing, Bitcoin's total computational power is over 100 Exahashes per second. Crypto hashes are very simple calculations, using SHA(256) in the case of Bitcoin hashing, with many repeated trials required until a winning result adhering to the pre-defined problem difficulty is achieved.

The problem difficulty is regularly adjusted by the consensus algorithm as the collective hashrate increases or decreases. Bitcoin has had over 300 such adjustments to data, on an approximate two-week schedule (each 2016 blocks).

Table 3: Hashrate History of Bitcoin since Block year two

Block Height	Block subsidy	Block Years elapsed	Date	Hashrate (TeraH/s)	log 10 of Hashrate	log 10 of Block Year	Power law, 4-year interval
105,000	50	2	2011-01-28	0.166	-0.78	0.30	
131,250	50	2.5	2011-06-16	7.705	0.89	0.40	
157,500	50	3	2011-12-14	8.249	0.92	0.48	
183,750	50	3.5	2012-06-09	12	1.08	0.54	
210,000	25	4	2012-11-28	25	1.40	0.60	
236,250	25	4.5	2013-05-15	87	1.94	0.65	
262,500	25	5	2013-10-09	1564	3.19	0.70	
288,750	25	5.5	2014-03-03	29,033	4.46	0.74	
315,000	25	6	2014-08-11	156,187	5.19	0.78	10.99
341,250	25	6.5	2015-01-31	296,921	5.47	0.81	12.47
367,500	25	7	2015-07-29	386,597	5.59	0.85	15.08
393,750	25	7.5	2016-01-17	766,473	5.88	0.88	16.32
420,000	12.5	8	2016-07-09	1,554,081	6.19	0.90	16.58
446,250	12.5	8.5	2017-01-02	2,420,682	6.38	0.93	14.88
472,500	12.5	9	2017-06-23	5,145,068	6.71	0.95	12.02
498,750	12.5	9.5	2017-12-11	12,845,067	7.11	0.98	9.95
525,000	12.5	10	2018-05-29	33,710,000	7.53	1.00	10.21
551,250	12.5	10.5	2018-11-24	41,483,900	7.62	1.02	11.15
577,500	12.5	11	2019-05-24	52,657,000	7.72	1.04	12.00
603,750	12.5	11.5	2019-11-14	89,789,000	7.95	1.06	11.84
630,000	6.25	12	2020-05-11	121,040,000	8.08	1.08	11.19
Last 4 years	HR ratio	77.62		R^2	0.97	slope	12.16
	CAGR	197%				intcpt	-4.88

Table 3 shows the Bitcoin hashrate history at one-half block year intervals, starting from when Bitcoin was two block years of age. Each block year is 52,500 blocks of approximately 10 minutes' duration, and block years are running slightly shorter than regular calendar years, recently by about two weeks. Since the May 11 Halving, we are now in the 13th Block year since Bitcoin's blockchain launched in January 2009.

In the table, the block height (number of blocks) is shown in the first column, then the block reward is shown in the following column. Note that it decreases by a factor of two each four block years; these are the key Halving events that drive inflation down toward zero. The calendar date is shown, then in the next column the total hashrate for all miners around the globe. Then we have the base 10 logarithm for the hashrate and the log of the block years elapsed. In the last column of the table one sees the four-year prior interval slope for a log - log regression (power law relationship) between hashrate and block years.

The hashrate is up by nearly eight orders of magnitude in the past four years. Hashrate has been growing extremely rapidly, roughly as the 12th power of elapsed block time! For a while in the 2014-15 period hashrate was growing with a power law > 15 as a rapid switch from GPUs to ASICs was underway. Now it has settled down somewhat to "only" a power law > 10 and still much, much faster than Moore's law.

This rapidly growing global hashrate is a result of strong advances in the specialized ASIC-based crypto mining ASIC-based computer designs, in performance, packaging, and power efficiency. It also reflects the optimization efforts of mining pools as they seek out the least costly locations for electrical power and cooling and optimize their facilities design. It is of course additionally a result of the long-term increase of Bitcoin price, some four orders of magnitude since early 2011, that has attracted ever-larger investment.

The price of Bitcoin has been growing roughly as the 5th power of elapsed block time, driven by enhanced security and scarcity as Bitcoin's inflation rate drops continually. Hashrate follows price as miners are incentivized to increase their capital investment in terms of the number of systems devoted to mining and by obtaining the latest and greatest hardware. The result is that the hashrate is increasing at roughly the square of the Bitcoin price.

Doubling Thrice each Two Years

In the last four calendar years, as indicated in Table 3, hashrate increased 77 times for Bitcoin, over six doublings, for a compound (calendar year) annual growth rate of 197%. This implies a doubling each eight months or *three times more rapidly than the Moore's law rate*.

Hashrate follows price, price reflects security (that depends on length of blockchain and hashrate as well) and growing scarcity (decrease in remaining supply or its inflation rate) that is a simple function of blockchain length. Inflation is cut in half at each Halving separated one from the next by four block years.

Mining inputs include capital equipment expense, facilities expense, personnel, electricity, cooling, as well as the expected price of Bitcoin or other cryptocurrency over the capital equipment life.

Since the major equipment cycle is around two years, the miners must look out a couple of years ahead and guesstimate costs and the future bitcoin price to justify new capital investment. If price drops they can shut down their least efficient equipment and only mine with their newer equipment that has the best hashrate per kilowatt characteristics. There may also be seasonal effects, especially since a lot of the miners are located in regions with cheap hydroelectric power that costs less when spring runoff is flowing. If some miners shut in some equipment, the more efficient miners will increase their share of bitcoin rewards, as the mining difficulty will decrease. Somebody gets the rewards, without fail.

Capex is sunk cost, so miners will continue to mine in the face of dropping prices as long as they can have positive cash flow after operating expenses (they may have to defer equipment upgrades, though, if cash is tight). They also can hedge their expected future production through forward sales with Bitcoin options or futures.

Summary Tables

Here we present tables of the top mined coins, top mining countries, and top pool operators (including multiple coins mined by a single operator).

As shown in Table 4, the total annual economic value for the top 50 mining pools is currently at a run rate of $4.82 billion per year. This is down from the November 2019 list by almost $3 billion, which can be ascribed directly to the Bitcoin Halving in May of this year. The Bitcoin price is up slightly since our last list, but Ethereum is up in price by about one third.

Of the top pools, 15 are mining Bitcoin, 16 are mining Ethereum, 4 are mining Zcash, and 6 Litecoin. The other 4 major mined coins have either two or three entries each. The percentage of annual economic value for Bitcoin has dropped from 84% of the total to 66%. Ethereum's share has increased to 24%, so the two coins are amounting to 90% of the value mined. The remaining 10% is spread across the 6 other significant coins. The Pareto principle is very much in evidence here.

Table 4: Top eight coins that have mining pools in the Top 50

Coin	Top 50 Pools: M$ per year	Number entries in Top 50	Percent of Annual Economic Value
Bitcoin	3166	15	65.8
Ethereum	1167	16	24.2
Litecoin	123	6	2.6
Zcash	113	4	2.3
Bitcoin Cash	81	3	1.7
Bitcoin SV	65	2	1.4
Ethereum Classic	61	2	1.3
Monero	38	2	0.8
Total	*4814*	*50*	*100*

Table 5: Top Host Countries

Host Country	Number of Top Pools	Percent of AEV	Annualized M$
China	19	32.1	1546
Global	17	32.7	1573
US	6	18.2	875
Hong Kong	5	12.9	623
Europe	1	3.6	174
Taiwan	1	0.2	10
Other	1	0.3	14
Totals	50	100	4814

In Table 5 we show the top countries. China clearly dominates as before, with 32% of the annual economic value. When one considers also that the Global category includes Chinese mining as well, the Chinese share is roughly 50%, and adding in Hong Kong, about 63%. The US share is around 18%. Crypto mining is certainly not banned in China, but is regulated with respect to access to electricity.

Table 6 shows the Top 10 pool operators, combining multiple coins mined by a given operator. Some operators are mining four or five of the top coins. If the entry is in the top 50 for pools of a given coin, it is aggregated in this list. F2Pool has moved into first place, displacing BTCdotcom from the #1 slot on the prior list. Poolin is #2 and AntPool is in #3 position, while BTCdotcom is #4 currently. We see that three of the top 10 pool operators are in China. Two are global, two are in Hong Kong, one is in the US, one in Europe, and one is located in both the US and China.

The production from the top 10 operators is almost $4 billion out of a total of $4.8 billion AEV produced by the top 50 pools

Table 6: Top Pool Operators

Pool Operator	Host Country	Number of Top Pools	Annualized M$
F2Pool	Global	5	832
Poolin	US, China	4	614
AntPool	China	3	492
BTCdotcom	Global	1	442
SparkPool	China	1	370
Ethermine	US	2	291
ViaBTC	Hong Kong	4	258
58Coin&1THash	China	1	228
OkExPool	Hong Kong	1	203
SlushPool	Europe	2	186
Totals		24	3,915

Tables 7a-7h in the Appendix show the full list of the top 50 cryptocurrency mining pools around the world, broken down by the top eight cryptocurrencies. Again, the cutoff is annualized economic value of $9.5 million or more. In these tables, a 30-day month is used, and a 365-day year.

The AEV production for the top 50 mining pools has decreased to a $4.8 billion rate from over $7 billion in the prior list. This approximately 1/3 decrease is due to the Bitcoin Halving. In the past month we have seen two downward adjustments in difficulty, with a decrease of 15%, as some mining rigs are taken away from Bitcoin production.

Models for Bitcoin's price and market cap such as PlanB's stock-to-flow model and Stephen Perrenod's future supply model suggest prices should continue to rise. We will see whether this occurs over the next year or two, pushing the AEV back toward the former high above $7 billion during this new Block era.

Appendix

Table 7a: Top Bitcoin Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	F2Pool	BTC	55.06	699.84	Global
2	Poolin	BTC	42.35	515.26	US, China
3	AntPool	BTC	37.46	455.74	China
4	BTCdotcom	BTC	36.29	441.53	Global
5	58Coin&1Thash	BTC	18.77	228.32	China
6	ViaBTC	BTC	17.52	213.21	Hong Kong
7	OkExPool	BTC	16.72	203.44	Hong Kong
8	SlushPool	BTC	14.31	174.12	Europe
9	HuobiPool	BTC	14.09	171.46	China
10	Lubian	BTC	14.09	171.46	Hong Kong
11	BinancePool	BTC	8.25	100.39	China
12	BTCdotTop	BTC	6.94	84.40	China
13	NovaBlock	BTC	3.87	47.08	US, Canada
14	SpiderPool	BTC	1.97	23.99	China
15	WAYIdotCN	BTC	0.80	9.77	China

Table 7b: Top Ethereum Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	SparkPool	ETH	30.44	370.41	China
2	Ethermine	ETH	21.93	266.80	US
3	F2Pool2	ETH	9.26	112.71	Global
4	NanoPool	ETH	7.73	94.03	Global
5	SpiderPool	ETH	5.95	72.36	China
6	Poolin	ETH	3.56	43.26	Global
7	MiningPoolHub	ETH	2.50	30.42	Global
8	Hiveon	ETH	2.20	26.80	Global
9	BeePool	ETH	1.67	20.28	China
10	Comining	ETH	1.41	17.15	Global
11	Pandaminer	ETH	1.28	15.56	China
12	Huobipool	ETH	1.26	15.35	China
13	PoolBTC	ETH	1.19	14.51	Global
14	XNPool	ETH	1.13	13.75	China
15	FirePool	ETH	0.88	10.76	China
16	GPUmine	ETH	0.79	9.58	Taiwan

Table 7c: Top Litecoin Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	Poolin	LTC	1.88	22.86	
2	F2Pool	LTC	1.60	19.43	Global
3	ViaBTC	LTC	1.18	14.35	Hong Kong
4	PoolBTC	LTC	1.10	13.38	Global
5	LitecoinPool	LTC	0.89	10.84	Global
6	AntPool	LTC	0.83	10.06	China

Table 7d: Top Zcash Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	Poolin	ZEC	2.66	32.31	Global
2	F2Pool	ZEC	1.16	14.06	China
3	SlushPool	ZEC	0.94	11.39	US
4	AntPool	ZEC	0.93	11.33	China

Table 7e: Top Bitcoin Cash Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	AntPool	BCH	2.15	26.18	China
2	unknown	BCH	1.16	14.15	n/a
3	ViaBTC	BCH	0.79	9.60	Hong Kong

Table 7f: Top Ethereum Classic Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	Ethermine	ETC	1.96	23.85	US
2	MiningPoolHub	ETC	0.84	10.17	Global

Table 7g: Top Bitcoin SV Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	ViaBTC	BSV	1.72	20.89	Hong Kong
2	F2Pool	BSV	1.30	15.80	China

Table 7h: Top Monero Mining Pools

Rank	Pool	Coin	Monthly M$	Annualized M$	Host Country
1	MinesXMR	XMR	1.10	13.36	Global
2	SupportXMR	XMR	0.84	10.22	US

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