



# THE BITCOIN MINING NETWORK

*Trends, Average Creation Costs,  
Electricity Consumption & Sources*

**JUNE 2019 UPDATE**

## *Foreword*

The Bitcoin mining industry is opaque, mysterious and misunderstood, but the health of the network supporting Bitcoin through mining is critical—vital actually—to the protocol. There is a lot of talk about investing in Bitcoin, trying to build a parallel financial system atop Bitcoin, using Bitcoin for payments or a safe-haven store of value, but there's not enough attention paid to securing the underlying network. Despite its outsized importance, there are serious questions around mining that have not been answered. Bitcoiners yearn for decentralization, but mining is still relatively centralized. To reach the decentralized future we all hope Bitcoin can achieve, and to understand Bitcoin at all, we need to understand the Bitcoin mining ecosystem. The need for adequate research in the Bitcoin mining network is imperative, but also no small feat. Collecting data points, trends, and estimates on the dynamics and economics of mining is nearly impossible without extensive, on-the-ground research. In such a secretive space, CoinShares stands out for their in-depth research on this topic.

At Fidelity's Center for Applied Technology, we believe the future of financial services will take place on open and permissionless ledgers like Bitcoin, but to truly understand the space requires rolling up your sleeves and diving deep into the technology. To understand Bitcoin mining, we knew we had to mine ourselves. Since the inception of our mining efforts in 2016, we have taken this "learn by trying" approach. As soon as we set up our first miners in a small shop at our office, we realized the mining industry is in a state of constant change. Over the past year, we have expanded our mining efforts to ramp up our knowledge of the space. We have explored optimal locations, hardware procurement, mining farm setups, and the economics of the mining industry as a whole.

Two interesting developments covered in the report are the insolvency of mining companies during the bear market and new trends in mining hardware manufacturing. It seems that every time we examine mining, we find ourselves on a new frontier, with miners and manufactures uncovering new ways to optimize and compete.

But the more things change, the more they stay the same. As CoinShares continues to highlight, chasing down the cheapest power remains the cornerstone of capturing competitive edge in Bitcoin mining. Power is the single complexity of the mining ecosystem that can be controlled or confined. You may not be able to control hashrate, price, or hardware costs/specs, but locking yourself into an advantageous electricity contract will allow for flexibility and profitability.

Mining is a profit-driven competition, but its most important function is securing the Bitcoin network. Anyone seeking to build a business around Bitcoin or investing in its long-term value proposition has an incentive to maintain the integrity of the Bitcoin network. So, as you hunt for nonces, we encourage miners to remember their utmost goal—securing Bitcoin for the future. The better we all understand the mining industry through cooperation and transparency, the stronger Bitcoin will be.

*Amanda Fabiano*

Fidelity Center for Applied Technology

# The Bitcoin Mining Network

- Trends, Composition, Average Creation Cost,  
Electricity Consumption & Sources

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**Note:** this white paper is provided subject to acceptance of the conditions contained on page 18.

## Abstract

In this report we investigate the geographical distribution, composition, efficiency, electricity consumption and electricity sources of the Bitcoin mining network. We also investigate trends in hashrate, hardware costs, hardware efficiency and marginal creation costs. Among our findings is an estimate that since November, the market-average, all-in marginal cost of creation, at €5/KWh, and 18-month depreciation schedules has decreased from approximately \$6,800 to approximately \$5,600, mainly as a result of lower assumed cooling and overhead costs. This suggests that, at current prices, the average miner is highly profitable, with even older gear and high-cost producers currently able to make positive ROI. Furthermore, we show that Bitcoin mining is mainly located in global regions where there are ample supplies of renewable electricity available. And finally, we calculate a conservative estimate of the renewables penetration in the energy mix powering the Bitcoin mining network at 74.1%, making Bitcoin mining more renewables-driven than almost every other large-scale industry in the world.

## Introduction

Here in the third iteration of our bi-annual mining report we continue our ongoing observations and analysis regarding the state of the Bitcoin mining network. From this report and onwards we will discontinue any explanatory treatment of mining as a concept and focus entirely on results. For readers wanting to familiarise themselves with—or revisit—the fundamentals and economics of the Proof-of-Work (PoW) mining utilised in Bitcoin, we recommend the following sources [1] [2] [3] [4].

Bitcoin's PoW miners continue to dominate the cryptocurrency mining industry both in terms of total revenue and total security spend. According to data from CoinMarketCap.io, over the course of 2018, Bitcoin miners received an estimated \$5.5bn in total block rewards, \$5.2bn (97%) of which was newly minted coins, and \$300m (3%) of which were transaction fees. At current

(31 May 2019) prices and 30d average fees per block, Bitcoin miners are earning an estimated total annualised return of \$6.2bn per year, 94% of which come from new coins and 6% from fees.

The recent increase in the ratio of mining fees as a component of the block reward is an interesting development and certainly a welcome development for miners, particularly considering the upcoming halving of the block reward, now less than a year away.

## Network Development

Since our last report of November 2018, the hashrate has grown from approximately 40 EH/s to approximately 50 EH/s, an increase of 25%. During this period the Hashrate grew slower than the 10-year average [Figure 3], but in line with the five-year average (the beginning of which—2014, marks the beginning of the industrial

mining era).

The 6 months passed can be roughly divided into two major eras: the final drop and subsequent bottoming-out of the hashrate—coinciding with the capitulation-phase of the Bitcoin price curve, and; the return to growth and near-full-recovery of the hashrate—coinciding with the recent rally in Bitcoin prices and the onset of the wet season in South-Western China. Meanwhile, Bitcoin prices have more than doubled from around \$4,000 to \$8,500 which has taken some pressure off the highest cost miners.

During the same period, we have observed two substantial macro trends, coinciding with the two above inter-period eras: 1) A large number of bankruptcies, liquidations and ownership transfers of mining units, often to more well-situated and capitalised miners whose new capital stock has been acquired at a much lower cost basis than their previous owners, and; 2) The first at-scale deployment of the latest generation mining gear.

It is also worth noting that the ~40% drop in hashrate observed at the tail-end of 2018 represents the first time we have ever observed a substantial and prolonged drop in hashrate as a result of sustained large-scale corrections in the Bitcoin price. As we explained in our Medium commentary at the time [3], this would not lead to a mining death-spiral. On the contrary, the system acted exactly in accordance with its design, with the difficulty lowering perfectly in-line with the hashrate reduction, decreasing mining costs in accordance with the reduced

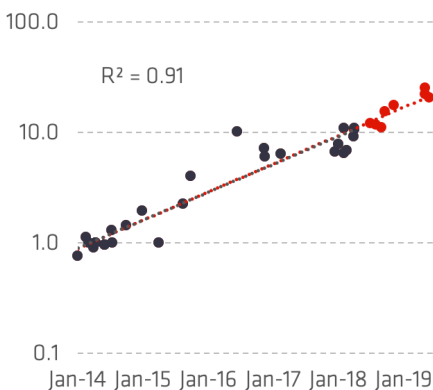
Bitcoin prices.

Returning to the second era of our 6-month observation period, we believe the recent spike in hashrate is caused by two separate drivers: 1) The re-starting of much of the previously shuttered mining gear as the Bitcoin price recovery has caused even previous-generation mining units to become cashflow positive at commonly attainable wet-season electricity prices, and; 2) Deployment of next-generation mining gear at appreciable scale, predominantly in Sichuan, in line with the advent of the wet-season. The efficiency and dollar cost per TH/s both keep improving in line with the five-year trends [Figures 1 and 2]. These efficiency gains are contributing to a current all-time high of mining efficiency of 11.5 GH/J, up from 10.5 GH/J in November 2018 (+10%).

We also note some jurisdictional developments in North America with consequences for local miners. In Oregon, miners have been facing unwelcome treatment both by local governments and electricity providers, leading to a mass exodus of miners from the state. On the other side of the US-Canada border, however, previous negative signals towards the industry from both governments and Hydro Quebec now seem to have reversed with both added clarity from regulators and less hostility towards miners on the part of utility providers.

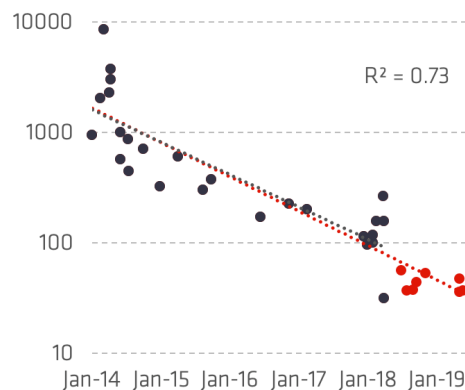
Lastly, we will briefly touch on the never-ending topic of Chinese mining trends. Over the last few years we have observed a steady trend of reduction of Chinese geographical dominance

Figure 1: Hardware Efficiency (GH/J) vs Shipping Date



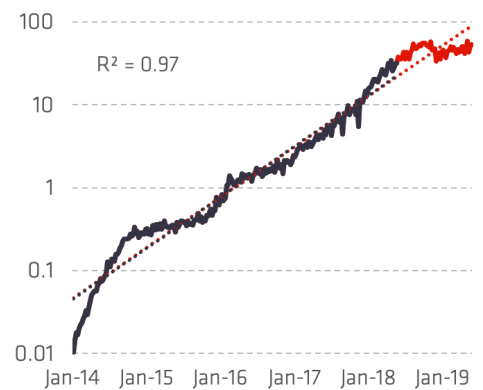
Sources: Bitcoin Wiki (May 2018), CoinShares Research (May 2019)

Figure 2: Hardware Cost (\$/TH/s) vs Shipping Date



Sources: Bitcoin Wiki (May 2018), CoinShares Research (May 2019)

Figure 3: Total Estimated Bitcoin Hashrate (EH/s)



Sources: blockchain.com (May 2019), CoinShares Research (May 2019)

among Bitcoin miners. However, this latest 6-month period has offered little evidence of that trend continuing at its previous rate. While it is too soon to make any judgement about whether or not the general trend is abating, we offer it as an interesting observation amid the current industry conditions.

On the other hand, Chinese dominance in the hardware manufacturing sector remains as strong as ever and is showing no immediate signs of reduction. Even if the most damning rumours of Bitmain's struggles were true (we have our doubts), it would have minimal impact on Chinese dominance in the miner manufacturing sector as all other relevant manufacturers are also Chinese.

Then there is the ongoing uncertainty of Chinese government policy towards miners, latest exemplified by an official note of increased scrutiny of mining [5]. This note caused customary panic in western media, but seem to have had little actual impact on Chinese miners. It is important to note that Chinese miners already operate in a legal grey area, with large differences in treatment between local jurisdictions, and that concrete, large-scale coordinated action on the ground would likely be required to effectively uproot miners. We also note that there appears to exist significant differences between local and national treatments of the mining industry, with certain local governments seemingly much more inclined to view the industry positively due to its vigorous revenue generation on municipal levels. With the exception of some miners rumoured to be 'unwelcome' in Inner Mongolia and Xinjiang during last year's dry-season, national-level Chinese policy restrictions on mining—at least thus far—seems to be much less of an issue 'on the ground' than we assume in the West.

#### *Average All-In Creation Cost (ROI Breakeven Level)*

As is customary we calculate and present our current estimates of market-wide average creation costs [Tables 1 – 5]. Our current estimate at  $\text{€}5/\text{kWh}$  and 18-month capex depreciation now stands at approximately  $\text{\$}5,600$  versus  $\text{\$}8,500$  in November [Table 3]. Also observable in the table, we see that certain segments of miners—particularly those with that highly coveted combination of very cheap electricity ( $\sim\text{\$}3/\text{kWh}$ )

and brand new next-generation gear (potentially enabling depreciation over 2-3 years) are able to mine Bitcoin at less than  $\text{\$}3,500/\text{btc}$  [Table 3]. This combination of circumstances becomes even more powerful if the miner has access to preferential pricing on their mining gear, such as miner-manufacturers [Tables 1 & 2]. Please see page 4 of our May 2018 report for a more detailed discussion of our modelling methodology [6].

Considering the recent relief rally in Bitcoin prices, we believe the mining industry is currently highly profitable, with both previous-generation hardware—though only at relatively cheap electricity costs ( $<\text{\$}5/\text{kWh}$ )—and next-generation hardware—even at relatively expensive electricity costs ( $>\text{\$}5/\text{kWh}$ )—currently able to generate a positive ROI [Figure 4].

We also note that as a result of the collapse in secondary market pricing of mining gear, and large ownership turnover during late-2018 to early-2019, the capex component of the total market-average creation cost (at  $\text{\$}5/\text{kWh}$  and 18-month depreciation schedule) has fallen from 53% at the time of our November 2018 report, to 38% at the time of writing. The two other components are Hashing Electricity Opex at 54% and Cooling and Other Opex (C&O Opex) at 8%.

#### *Average Cashflow Breakeven Levels*

The other important cost level to consider is the cashflow breakeven level. As we have detailed in our previous work (3), this level is critical for estimating the price level below which the average miner would have to start shutting down his mining equipment. While ROI breakeven levels are also important, sustained prices below such levels only wipe out miner capital, causing changes in industry ownership ratios over time, whereas prices below cashflow breakeven levels cause immediate hashrate reductions.

Our estimate for the current market-average cashflow breakeven at  $\text{\$}5/\text{kWh}$  and 15% additional C&O Opex is  $\text{\$}3,300$ , up from  $\text{\$}3,000$  in November 2018. We attribute this increase mainly to the  $\sim 25\%$  increase in total hashrate, tempered by the  $\sim 10\%$  increase in mining gear efficiency. We also caution that our model operates on the basis of hashrate, not difficulty, meaning that it will tend to overestimate cash (and ROI) costs in times of hashrate growth and underestimate it in times of hashrate reduction.



Table 1: Market-Wide Creation Cost (US\$/BTC) at 15% C&O OPEX and -50% Below Standard CAPEX Assumption

| -50% CAPEX<br>+15% C&O OPEX<br>Electricity OPEX | CAPEX Horizon (Depreciation Schedule) |           |           |           |          |
|---|---------------------------------------|-----------|-----------|-----------|----------|
|   | 30 Months                             | 24 Months | 18 Months | 12 Months | 6 Months |
| 0.01 \$/kWh                                     | 1,344                                 | 1,516     | 1,803     | 2,377     | 4,100    |
| 0.03 \$/kWh                                     | 2,653                                 | 2,826     | 3,113     | 3,687     | 5,409    |
| 0.05 \$/kWh                                     | 3,963                                 | 4,135     | 4,422     | 4,996     | 6,719    |
| 0.07 \$/kWh                                     | 5,272                                 | 5,445     | 5,732     | 6,306     | 8,028    |
| 0.09 \$/kWh                                     | 6,582                                 | 6,754     | 7,041     | 7,615     | 9,338    |

Source: CoinShares Research (May 2019)

Table 2: Market-Wide Creation Cost (US\$/BTC) at 15% C&O OPEX and -25% Below Standard CAPEX Assumption

| -25 CAPEX<br>+15% C&O OPEX<br>Electricity OPEX | CAPEX Horizon (Depreciation Schedule) |           |           |           |          |
|--|---------------------------------------|-----------|-----------|-----------|----------|
|  | 30 Months                             | 24 Months | 18 Months | 12 Months | 6 Months |
| 0.01 \$/kWh                                    | 1,688                                 | 1,947     | 2,377     | 3,238     | 5,822    |
| 0.03 \$/kWh                                    | 2,998                                 | 3,256     | 3,687     | 4,548     | 7,132    |
| 0.05 \$/kWh                                    | 4,307                                 | 4,566     | 4,996     | 5,857     | 8,441    |
| 0.07 \$/kWh                                    | 5,617                                 | 5,875     | 6,306     | 7,167     | 9,751    |
| 0.09 \$/kWh                                    | 6,926                                 | 7,185     | 7,615     | 8,477     | 11,060   |

Source: CoinShares Research (May 2019)

Table 3: Market-Wide Creation Cost (US\$/BTC) at 15% C&O OPEX at the Standard CAPEX Assumption

| Standard CAPEX Assumption<br>+15% C&O OPEX<br>Electricity OPEX | CAPEX Horizon (Depreciation Schedule) |           |           |           |          |
|--|---------------------------------------|-----------|-----------|-----------|----------|
|  | 30 Months                             | 24 Months | 18 Months | 12 Months | 6 Months |
| 0.01 \$/kWh  | 2,033                                 | 2,377     | 2,951     | 4,100     | 7,545    |
| 0.03 \$/kWh  | 3,342                                 | 3,687     | 4,261     | 5,409     | 8,854    |
| 0.05 \$/kWh  | 4,652                                 | 4,996     | 5,570     | 6,719     | 10,164   |
| 0.07 \$/kWh  | 5,961                                 | 6,306     | 6,880     | 8,028     | 11,473   |
| 0.09 \$/kWh  | 7,271                                 | 7,615     | 8,189     | 9,338     | 12,783   |

Source: CoinShares Research (May 2019)

Table 4: Market-Wide Creation Cost (US\$/BTC) at 15% C&O OPEX and +25% Above Standard CAPEX Assumption

| +25 CAPEX<br>+15% C&O OPEX<br>Electricity OPEX | CAPEX Horizon (Depreciation Schedule) |           |           |           |          |
|--|---------------------------------------|-----------|-----------|-----------|----------|
|  | 30 Months                             | 24 Months | 18 Months | 12 Months | 6 Months |
| 0.01 \$/kWh                                    | 2,377                                 | 2,808     | 3,526     | 4,961     | 9,267    |
| 0.03 \$/kWh                                    | 3,687                                 | 4,117     | 4,835     | 6,270     | 10,577   |
| 0.05 \$/kWh                                    | 4,996                                 | 5,427     | 6,145     | 7,580     | 11,886   |
| 0.07 \$/kWh                                    | 6,306                                 | 6,736     | 7,454     | 8,889     | 13,196   |
| 0.09 \$/kWh                                    | 7,615                                 | 8,046     | 8,764     | 10,199    | 14,505   |

Source: CoinShares Research (May 2019)

Table 5: Market-Wide Creation Cost (US\$/BTC) at 15% C&O OPEX and +50% Above Standard CAPEX Assumption

| +50 CAPEX<br>+15% C&O OPEX<br>Electricity OPEX | CAPEX Horizon (Depreciation Schedule) |           |           |           |          |
|--|---------------------------------------|-----------|-----------|-----------|----------|
|  | 30 Months                             | 24 Months | 18 Months | 12 Months | 6 Months |
| 0.01 \$/kWh                                    | 2,722                                 | 3,238     | 4,100     | 5,822     | 10,990   |
| 0.03 \$/kWh                                    | 4,031                                 | 4,548     | 5,409     | 7,132     | 12,299   |
| 0.05 \$/kWh                                    | 5,341                                 | 5,857     | 6,719     | 8,441     | 13,609   |
| 0.07 \$/kWh                                    | 6,650                                 | 7,167     | 8,028     | 9,751     | 14,918   |
| 0.09 \$/kWh                                    | 7,960                                 | 8,477     | 9,338     | 11,060    | 16,228   |

Source: CoinShares Research (May 2019)

Table 6: Market-Wide Average Cashflow Breakeven Levels

| Electricity OPEX | Additional Cooling & Other (C&O) OPEX |       |       |       |       |
|------------------|---------------------------------------|-------|-------|-------|-------|
|                  | 5%                                    | 10%   | 15%   | 20%   | 25%   |
| 0.01 \$/kWh      | 598                                   | 626   | 655   | 683   | 712   |
| 0.03 \$/kWh      | 1,793                                 | 1,879 | 1,964 | 2,050 | 2,135 |
| 0.05 \$/kWh      | 2,989                                 | 3,131 | 3,274 | 3,416 | 3,558 |
| 0.07 \$/kWh      | 4,185                                 | 4,384 | 4,583 | 4,783 | 4,982 |
| 0.09 \$/kWh      | 5,380                                 | 5,637 | 5,893 | 6,149 | 6,405 |

Source: CoinShares Research (May 2019)

### Electricity Draw

As of the time of writing, we estimate the total electricity draw of the entire Bitcoin mining industry to be approximately 4.7 GW. This is the same estimate as in November 2018, but includes a caveat. In our last report we estimated that miners on average used 20% additional electricity—on top of that required by hashing—for cooling. We now understand that estimate to be grossly overstated and have reduced it to 10%. Meanwhile, the current amount of energy required for hashing *alone* is estimated to be ~4.3 GW, up from 3.9 GW in November 2018. This result is also broadly in line with a ~25% increase in hashrate and a ~10% increase in gear efficiency. On an annualised basis, we estimate that the network currently draws the equivalent of ~41 TWh.

It is worth mentioning here that as a general principle, the Bitcoin mining network will consume as much electricity as the market is willing to sell it in return for the total value of the

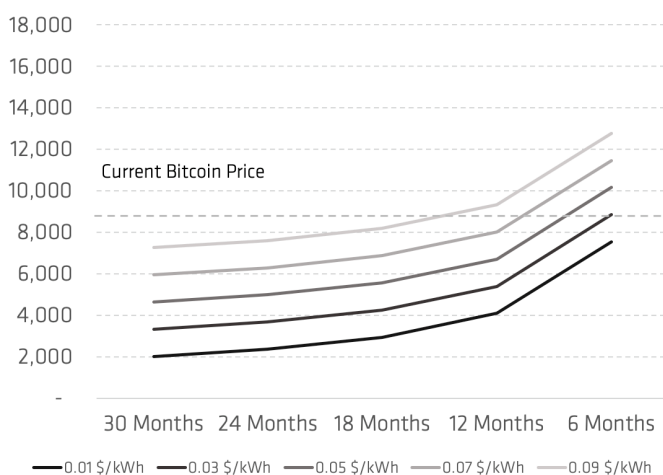
block reward (new coins plus fees), minus a competitive margin. This means that increasing the efficiency of mining gear has no impact on the total electricity draw of the network, it can only increase the hashrate per unit of electricity consumed. Over the long term, it is only the value of the block reward that can impact the network's total electricity draw.

### Geographical Distribution of Miners

Bitcoin miners are fairly well distributed across the globe [Figure 6], however they do have a significant tendency to cluster into certain similar geographies. Looking more closely at their distribution, it is clear that they are predominantly—by volume weight—confined to technologically advanced, relatively sparsely populated, hilly or mountainous regions traversed by powerful rivers.

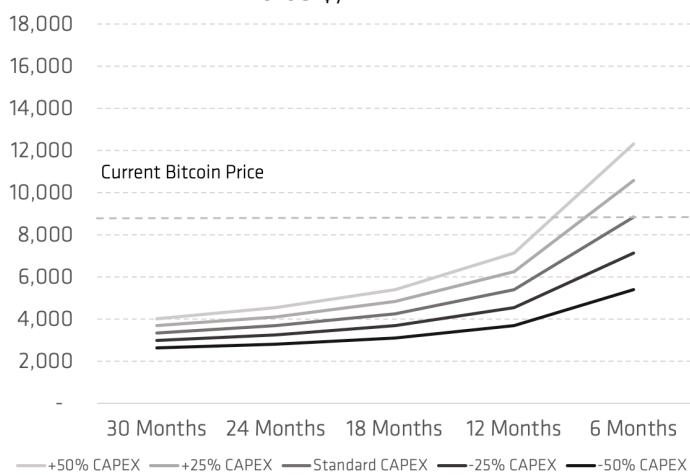
Among these regions we find the major mining centres of: Washington and New York States in the United States; British Columbia, Alberta, Newfoundland and Labrador, and Quebec

Figure 4: Sensitivity of Marginal Creation Cost to Electricity OPEX and CAPEX Horizon



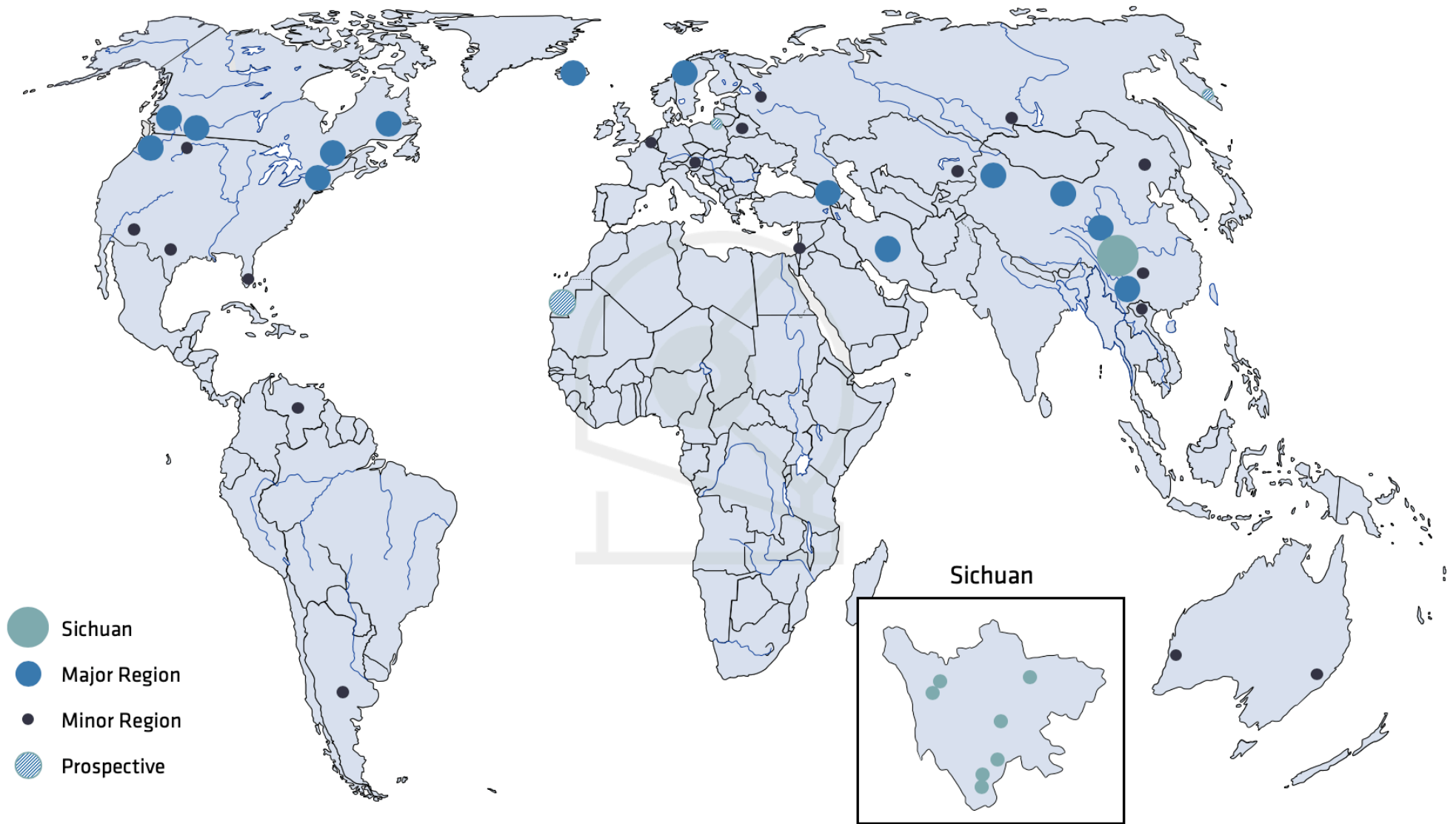
Source: CoinShares Research (May 2019)

Figure 5: Sensitivity of Marginal Creation Cost to CAPEX Assumption Size and CAPEX Horizon at 0.05 \$/kWh



Source: CoinShares Research (May 2019)

Figure 6: Global Overview of Bitcoin Mining Regions. Regions With Large Relevant Regions Shown in Blue, Sichuan in Teal and Remaining Minor Regions in Black





Provinces of Canada; Iceland; Northern Scandinavia (Norway and Sweden); The Caucasus (Georgia and Armenia); Yunnan and most importantly of all regions, Sichuan, provinces of China. There are also minor mining centres found in similar geographies such as Austria, Montana in the United States, Guizhou Province in China and the Siberian Federal District of Russia.

The remaining major mining regions which do not fit into the above geographical mould are Iran, and Xinjiang and Inner Mongolia provinces of China. Minor mining regions where the above described geography does not (or where we cannot be certain that it does) fit the above description include: Florida, Texas and Arizona in the United States; Western Australia and New South Wales states of Australia; Belgium; Belarus; the North West Federal District of Russia; Argentina; Venezuela; and Israel. See map for list of sources.

#### *Energy Mix*

Building on our increasing visibility of the mining industry as a whole, we continue our ongoing reporting on the likely energy mix of the input energy in the mining industry. Again, we refer back to our previous reports—in this case page 5 of our November 2018 report—for a more detailed discussion of the methodology and background of the investigation. For more casual readers, however, we summarise our methodology in simplified terms below.

Our main assumption is that miners, wherever they are located, utilise the same mix of power generation (fossil/nuclear or renewable) as the average reported in their region. We then estimate the total percentage of hashrate residing in each relevant region, down to the lowest administrative subdivision for which reports of energy mix are available. Finally, we multiply the percent of renewables penetration in each relevant mining region with the percent of the total global mining industry residing in that region to arrive at a global weighted average estimate of renewables penetration in the Bitcoin mining network's total energy generation [Tables 7 - 9].

From the previous section (*Geographical Distribution of Miners*) readers will note that we divided the geographical clusters of Bitcoin miners into two main baskets. We will call the

first basket the hydro regions and the second basket the non-hydro regions. The hydro regions, as implied by the name, are global regions of hydro-power abundance.

In the remaining regions we observe a mix of fossil, nuclear, solar and wind generation sources, with some, such as Iran, dominated by natural gas, and others, such as Xinjiang and Inner Mongolia, dominated by coal and supplemented with wind. While there exist miners using solar as their main power source, such operations are still relatively rare.

We currently estimate that 60% of global mining happens in China, and that Sichuan alone produces 50% of global hashrate, with the remaining ten percent split more or less evenly between Yunnan, Xinjiang and Inner Mongolia. Our estimate for Sichuan's dominance within both China and the world is marginally higher than in our last report and is a result of the 'Fengshui' rainy season in the hydro-heavy 'Yunguichuan' (colloquial name for Yunnan, Guizhou and Sichuan, here, awkwardly in latin alphabet) provinces of Southwestern China. During this period, electricity prices are among the lowest in the world, making it one of the most attractive global mining regions available. We expect this estimate to drop in our next report (November 2019) as many miners migrate towards Xinjiang and Inner Mongolia for the dry season, but more on that in the next section.

Out of the remaining 40% of miners, we estimate that 35% of global hashrate production is evenly split between Washington, New York, British Columbia, Alberta, Quebec, Newfoundland and Labrador, Iceland, Norway, Sweden, Georgia and Iran. The last 5% is assumed to be distributed widely enough that the global average energy mix is a good enough fit to estimate their energy sources. These estimates and the corresponding regional renewables penetrations are summarised in Table 9.

Using the above methodology, we arrive at a new lower-bound estimate of 74.1% renewables penetration in the mining energy mix. The reason we consider it a lower bound is that we believe our methodology to be highly conservative in its treatment of certain regions where we know miners are using renewable energy sources even though the regional average is less than 100%,

such those in New York.

The renewables estimate is down from 77.8% in our November 2018 report and reflects increased visibility of the industry on our part as well as movements within the industry. For example, we have observed a significant exodus of Oregon miners as well as an influx into natural-gas-dominated areas such as Iran.

#### Seasonality Factors of the Energy Mix

As we have alluded to in previous sections we continue to observe moderate seasonal mobility, especially among Chinese miners. We believe this mainly to be a result of the seasonal variability in rainfall, and consequently hydro power prices, in the ‘Yunguichuan’ region of Southwestern China. As the annual ‘Fengshui’, or wet season, period manifests, electricity prices fall as low as €2.5/kWh, and generally to levels that are among the lowest in the world. Multiple sources suggest that more than 100 TWh of electricity could be wasted annually across these three provinces alone [44] [45] [46].

When the dry season returns, electricity prices rise again, causing some miners to migrate to Xinjiang and Inner Mongolia where cheap coal and wind power is available year around. Some sources suggest that as many as 500,000 mining units migrated to and from Xinjiang last year [47]. Migration, however, is an expensive endeavour restricted to the most well-capitalised miners with 7-figure (US\$) relocation costs and 20% breakage rates reported.

Combined, these migration patterns will cause seasonal variability in the renewables penetration of the Bitcoin mining industry. We

Table 7: Chinese Renewables Penetration by Province

| Relevant Chinese Provinces | Renewables Penetration |
|----------------------------|------------------------|
| <b>Sichuan (2017)</b>      | <b>90%</b>             |
| Yunnan (2017)              | 92%                    |
| Inner Mongolia (2017)      | 16%                    |
| Xinjiang (2017)            | 23%                    |
| <b>Average ex. Sichuan</b> | <b>44%</b>             |

Source: Morgan Stanley Research (Oct 2018)

therefore expect our estimates of total renewables penetration in the mining energy mix to vary somewhat with the seasons.

#### Caveats and Uncertainty Factors

It is necessary at this point to caveat that while we do our utmost to accurately pinpoint the location of global mining centres, the Bitcoin mining industry remains a highly private and secretive industry. As a result, our estimates may be subject to significant potential uncertainty. While we have made no attempt to formally quantify these uncertainly levels, we intuitively guesstimate that, e.g. our renewables penetration figures should be taken to include a tentative uncertainty of around ±10%.

That being said, we confidently consider our numbers to be amongst the best available in the industry. For other estimates using survey-based methodologies we refer readers to the following sources [48] [49].

#### Conclusion

The Bitcoin mining network continues to develop along its five-year trend-lines on metrics of efficiency increase, investment cost reduction and hashrate growth.

After having emerged from one of the most challenging price environments ever observed in

Table 8: Non-Chinese Renewables Penetration by Country, State or Province

| Relevant Non-Chinese Countries/States/Provinces | Renewables Penetration |
|---|------------------------|
| Washington (2016)                               | 92%                    |
| New York (2016)                                 | 45%                    |
| Alberta (2018)                                  | 11%                    |
| British Columbia (2018)                         | 98%                    |
| Quebec (2018)                                   | 100%                   |
| Newfoundland and Labrador (2018)                | 95%                    |
| Norway (2016)                                   | 99%                    |
| Sweden (2016)                                   | 65%                    |
| Iceland (2016)                                  | 100%                   |
| Iran (2017)                                     | 0%                     |
| Armenia (2017)                                  | 33%                    |
| Georgia (2016)                                  | 79%                    |
| <b>Average</b>                                  | <b>68%</b>             |
| <b>Rest of the World</b>                        | <b>18.2%</b>           |

Sources: EIA (Nov 2018), R2E2 (Jul 2017), Natural Resources Canada (Sep 2018), SATBA (Feb 2017)

Table 9: Breakdown of Global Renewables Penetration in Bitcoin Mining

| Region                       | Global Mining Share | Renewables Penetration | Share of Renewables for Mining | Share of Fossil/Nuclear for Mining |
|------------------------------|---------------------|------------------------|--------------------------------|------------------------------------|
| Sichuan                      | 50.0%               | 90.1%                  | 45.1%                          | 5.0%                               |
| Relevant Remaining China     | 10.0%               | 43.6%                  | 4.4%                           | 5.6%                               |
| Relevant Non-Chinese Regions | 35.0%               | 68.0%                  | 23.8%                          | 11.2%                              |
| Rest of World                | 5.0%                | 18.2%                  | 0.9%                           | 4.1%                               |
| <b>Global Total</b>          | <b>100.0%</b>       |                        | <b>74.1%</b>                   | <b>25.9%</b>                       |

Sources: Morgan Stanley Research (Oct 2018), EIA (Nov 2018), Natural Resources Canada (Sep 2018), R2E2 (Jul 2017), SATBA (Feb 2017), CoinShares Research (May 2019)

the industry, miners now appear generally healthy and profitable at current price levels.

Over the last six months we have observed significant liquidations of miners and a high corresponding turnover in mining gear. While this has certainly been painful for the eliminated miners, the remaining ones are now much better equipped to handle further market downturns, should they emerge.

Miners are still majorly confined to regions dominated by cheap hydro-power, such as Scandinavia, The Caucasus, The Pacific North West, Eastern Canada and Southwestern China. We believe this to be a direct consequence of the extremely low electricity prices available in these regions, especially where the hydro-power is relatively under-utilised.

Where we previously had observed a strong tendency of miners moving out of China, the preceding six months have not shown many signs of this trend continuing. Here we also want to caution that the arrival of the 'Fengshui' wet season might be a complicating factor as Chinese miners would likely be unwilling to risk international relocation in the face of upcoming boons in domestic electricity pricing.

The migrations we do observe are mainly confined within China where miners will opportunistically relocate their gear between Xinjiang/Inner Mongolia in the dry season and Sichuan/Yunnan/Guizhou in the wet season. While this is certainly an interesting pattern certain factors such as high relocation costs and breakage rates seem to act as dampening factors to the overall migratory behaviour.

Finally, using a combination of estimates of global mining locations and regional renewables penetrations we again calculate the Bitcoin mining industry to be heavily renewables-driven. Our current approximate percentage of renewable power generation in the Bitcoin mining energy mix stands at 74.1%, more than four times the global average.

This estimate is marginally lower than our November 2018 estimate of 77.8%, reflecting the upstart of major mining clusters in fossil-dependent regions such as Iran as well as relocation away from hydro-dependent regions such as Oregon.

Overall, our findings reaffirm our view that Bitcoin mining is acting as a global electricity buyer of last resort and therefore tends to cluster around comparatively under-utilised renewables infrastructure. This could help turn loss making renewables projects profitable and in time—as the industry matures and settles as permanent in the public eye—could act as a driver of new renewables developments in locations that were previously uneconomical.

## Appendix

### *Specific Assumptions*

(CoinShares Research Assumption Rating Strength from 0 – 10)

This is a list of old and updated/new assumptions. Where updates have been added we have placed them in brackets, and where the updates are recent to this report they are in brackets and *italics*.

### Mining Unit Cost in US\$

All unit prices are attempts at volume weighted averages across the entire hardware life cycle and at the cost incurred by current hardware holders.

### *Bitfily:*

US\$ 899 – 8/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [50]. The price is pulled from the website of the retailer at the last time available. Therefore, we are quite confident this at least accurately represents the retail price even if it does not fully capture the second-hand prices. For less popular miners such as this there are not enough second-hand sales to get a good idea of secondary market pricing.

### *Bitfury Block Box:*

US\$ 1,300,000 – 8/10

This is a composite estimate from private conversations with Bitfury where we simply take the average of their two options, with and without immersion cooling.

### *Private Bitfury Facilities:*

US\$ 400,000 – 4/10

This assumption is an order of proportionally scaling Song's Bitmain supply cost [51] onto Bitfury and then doubling the per-chip cost to reflect higher costs of the full set up and the higher production costs suggested by the lower success of Bitfury relative to Bitmain.

### *Bitfury Tardis:*

US\$ 5,070 – 6/10

The Bitfury Tardis does not have information available from the retailer, however, from other people that have inquired we understand that the price is dependent on the amount of hashboards and efficiency one prefers. The upper bound – the price we use – is \$5,070. This is a Tardis assembled using 'Clarke' chips using 8 chipboards doing about 78 TH/s at \$65 per TH/s. Thus, the machine is assumed to cost  $78 * 65$  which is 5,070. The most efficient machine but with the least hashrate is a Tardis assembled with the same chips but using only 5 hashboards. It comes out at 66 TH/s and the price is \$55 per TH/s thus for this machine you get  $66 * 55 = 3,630$ . To be conservative we assume the miners are operating more firepower trading off efficiency, even if we don't think this is necessarily the case as they are likely to optimise and even reconfigure in operation.

### *Bitfury x Hut 8:*

US\$ 1,300,000 – 8/10

See above assumption for privately sold Bitfury units.

### *Antminer S7:*

US\$ \$50 – 3/10

*[Update May 2019. It is very hard to update the price of this assumption so we have simply scaled down the certainty. With Bitcoin prices where they are at the time of writing it is assumed some people have turned at least a few of these units back on.]*

### *Antminer S9 Publicly Available Units:*

US\$ 390 – 7/10

*[Update May 2019. Recently in China, 1,000 is frequently cited by miners both in interviews and on forums, blogs and social media platforms. We also discovered a lot that larger mines can get for as low as 700 or 800 yuan and we also heard from a particular source in the West they were as low as 150 USD. Sources are Mr Nasser, Yu Wei (the former head of a Bitmain mine [52]) and Liu Feng*

(a miner connected enough to be amongst the first miners to find preferential rates in Iran [53]).

Some miners will have held on to their miner since their original investment. So, we took there to be roughly 2,000,000 S9 and assume 75% of them have changed hands. We took a weighted average across the four data points we have: i) the price from our previous report, ii) the price we believe was wholesale for Western mines, iii) the price we heard most frequently from Chinese sources and iv) the price we heard for wholesale amongst Chinese miners.

25% @ November's 1,100 weighted average - 1,100 USD

25% @ Ray Nasser, via Telegram says other Western prices reported - 200 USD

25% @ Yu Wei, former head of Bitmain Mine says 1,000 yuan, roughly - 150 USD

25% @ Liu Feng, well connected miner says on average 750 yuan, roughly 110 USD

Taking the average returns \$390]

*Antminer S9 Private Bitmain Facilities:*

US\$ 500 - 7/10

Here we base the assumption on an article by Jimmy Song entitled "Just how profitable is Bitmain?" [51].

[Update November 2018: We do not believe Bitmain have added any more S9's to their private facilities since May.]

*Antminer S15 Private Bitmain Facilities:*

US\$ 500 - 7/10

At the time of writing this unit has not yet began shipping to the public even though payment has been taken both domestically on their Chinese e-shop and on the international website. The estimate is based on a similar ratio of the retail price compared to the price that Song calculated in his article [51]. While we appreciate that 7nm chips are more expensive than 16nm chips, we also believe Bitmain have unlocked significant economies of scale since their first introduction of the S9.

*Avalon 841:*

US\$ 415 - 7/10

Assuming the officially stated price is accurate.

[Update November 2018: We have been unable to find any new price information as previous information was taken from Chinese sources. This is significant because the vast majority of Canaan's customers are domestic; previously it has been as high 99.6% yet as of 2017 it still remains as high as 91.5%] Unfortunately, this source has since been removed.

*Avalon 921:*

US\$ 742 - 7/10

Assuming the officially stated price is accurate.

[Update November 2018: We have been unable to find any new price information as previous information was taken from Chinese sources. This is significant because the vast majority of Canaan's customers are domestic; previously it has been as high 99.6% yet as of 2017 it still remains as high as 91.5%] Unfortunately, this source has since been removed.

*Ebang E10:*

US\$ 1800 - 7/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [50]. The price is pulled from the website of the retailer at the last time available. Therefore, we are quite confident this at least accurately represents the retail price even if it does not capture the second-hand prices. For less popular miners such as this there are not enough second-hand sales to get a good idea of secondary market pricing.

*GMO Mining B2/B3:*

US\$ 1,999 - 9/10

This price is listed on their website [54].

*DragonMint T1:*

US\$ 1,199 - 7/10

This assumption is based on the price of batch 1. We know of no further batches but have seen a



lot of people exchanging these for lower prices and so have altered the price down to reflect secondary market conditions. This is also to match the price on the Bitcointalk.org.

*Innosilicon T2 Turbo:*

US\$ 1,350 – 7/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [50]. The price is pulled from the website of the retailer at the last time available. Therefore, we are quite confident this at least accurately represents the retail price even if it does not capture the second-hand prices. For less popular miners such as this there are not enough second-hand sales to get a good idea of secondary market pricing.

*MicroBT's Whatsminer M10:*

US\$ 1,441 – 7/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [50]. The price is pulled from the website of the retailer at the last time available. Therefore, we are quite confident this at least accurately represents the retail price even if it does not capture the second-hand prices. For less popular miners such as this there are not enough second-hand sales to get a good idea of secondary market pricing.

Total Mining Units

*Bitfily:*

1,000 – 3/10

This estimate is low because the amount of information available is equally small. We therefore have little to no information about sales. Having said that, considering the mediocre specifications of this hardware there is nothing to indicate this unit has sold much more than 1,000 copies.

*Bitfury Block Box:*

448 – 4/10

Here we use market estimates of approximately

12% of total hashrate (28 exahash) as stated by the CEO of Bitfury to reverse-arrive at 448 by using stated efficiency figures.

[Update November 2018: We have carried the assumption over but scaled the assumptions certainty down by a factor of one to reflect the inevitable decrease in certainty as time passes from the last data point.]

*Private Bitfury Facilities:*

112 – 6/10

This assumption is reverse calculated from Bitfury investor presentations stating 132 megawatts and subtracting off the known 'Hut 8' units leaving Bitfury's own facilities.

[Update November 2018: This figure has just been brought forward but knocked down a point as Bitfury have released a new chip and sold some Block Boxes [55] publicly and thus presumably a few privately as well.

*Bitfury Tardis:*

1,000 – 5/10

The Bitfury Tardis is a very new miner with their new 'Clarke' chips and so it is assumed very few have been sold so far. The only sale we know of is the aforementioned one to Hut 8.

*Bitfury x Hut 8:*

85 – 10/10

This information is available to us by email from Hut 8 and as a publicly listed company we have strong reason to believe this is entirely accurate.

*Antminer S7 Series:*

1,000 – 5/10

We have assumed a certain small amount of these miners has come back online considering price of Bitcoin at the time of writing. However, these miners are few and far between where the operator essentially has access to 'free' electricity. For example, Upstream Data.

#### *Antminer S9 Publicly Available Units:*

1,730,000 – 7/10

Bitmain's S9 and other very similar hardware from Bitmain (T9's and all other versions of the S9) are widely assumed by many mining experts and large-scale miners to be the vast majority of the network at about 2/3 of all miners in their efficiency class.

*[Update May 2019: Previously I had estimated about 1,950,000 S9 machines were in use privately. Mao Shing, founder of the F2Pool (one of the largest in the world), thinks between 600,000 and 800,000 mines have been turned off. Given the kind of mine that would be turned off is around this level of efficiency and the prolific role of the S9 in this bracket, I took the average and removed that from the figure of S9's operating.]*

*\*The speaker says that amount fell off in November, so we take it off the highest figure but given the new price levels and lagging difficulty it's possible for miners to be making good profits even at 7 cents [56] [57]. Thus, we have assumed that at least half of the S9's that were taken off due to price levels have been fired back up. Another 130,000 have been added see below 'S9 Private'.]*

#### *Antminer S9 Private Bitmain Facilities:*

100,000 – 7/10

Here we base our assumption on remarks from Bitmain employees and interviews from Quartz articles on Bitmain (<https://qz.com/search/bitmain>, all worth reading) and Chinese news sources covering Bitmain. The Chinese sources suggest that the mine in Xinjiang is 'three times' the size of the Ordos mine of 25,000 machines; that the Xinjiang mine and the Sichuan and Yunnan mines have a migratory cycle based on the abundance of wind and solar in the dry season (Xinjiang, Northwest) [58] [59] and the hydropower of Sichuan and Yunnan in the rainy season (Southwest) [58]; and lastly that they have facilities like it elsewhere in China and the world (such as in Anhui and Newfoundland [17])

*[Update November 2018: This figure has been brought forward despite Bitmain's assumed making and selling of units. Their IPO documents state that their private mining operations are*

limited and we have therefore assumed no additional gear added. Unfortunately, this source has since been removed.

*Update May 2019: This figure has reduced by 130,000 as Bitmain have taken 130,000 offline including having made a sale of 100,000 or more. They have been added to the mining S9's as a result [60] [61].*

#### *Antminer S15 Private Bitmain Facilities:*

120,000 – 5/10

Although this miner has only just been announced it is well known that Bitmain does not mind mining on gear before it is released to the public and so we have assumed that it has a significant amount of these mining already.

*[Update May 2019 According to Coindesk and multiple Chinese sources 200,000 Bitmain miners have been deployed. They are potentially all S17 since they are for themselves to mine with and so it's likely they gave themselves the best gear, but for now, as its an assumption already, we have split them across both models evenly. There are 20,000 extra S15 in D15 as we had previously assumed 20,000 of this model had already been deployed [61] [62].*

#### *Antminer S17 Private Bitmain Facilities:*

100,000 – 5/10

*According to Coindesk and multiple Chinese sources 200,000 Bitmain miners have been deployed. They are potentially all S17 since they are for self-mining and so it's likely they gave themselves the best gear. For now however, as this is an assumption already, we have split them across both models evenly. There are 20,000 extra S15 in D15 as we had previously assumed 20,000 of this model had already been deployed [61] [62].*

#### *Antminer S17*

20,000 – 3/10

*There has been some S15 and S17 shipped we assume but we do not know much about figures yet.*

### *Avalon 7-series*

5/10 - We have assumed a certain small amount of these miners has come back online considering the price of Bitcoin at the time of writing. Of course, this only applies to particular locations where electricity rates meet the needs of miners like in Canada or China. It would be assumed most of these remain in China and so are being used in the hydro-centric areas of Sichuan and neighboring provinces.

### *Avalon 841:*

225,000\* - 6/10

This is estimated from extrapolating inferred production runs given the reports of total amount of hardware sold in Canaan's IPO application. Unfortunately, this source has since been removed.

### *Avalon 921:*

75,000 - 6/10

This is estimated from extrapolating inferred production runs given the reports of total amount of hardware sold in Canaan's IPO application. Unfortunately, this source has since been removed.

### *Ebang E10:*

200,000 - 6/10

This is an estimate back-calculated from the percentage of hardware claimed by Ebang to be produced in 2017 and carried forward. This figure is independently calculated by a company commissioned to do the work for their IPO application and they expect that Ebang accounted for 11% of hardware produced in 2017. This is mentioned on various occasions, first on page 1. The reason we do not consider it entirely reliable is that as we have seen little evidence of a market share of that magnitude, and that the report supporting the IPO application documents was commissioned by Ebang themselves. Unfortunately, this source has since been removed.

### *GMO Mining B2/B3:*

16,000 - 8/10

As with the previous estimate for GMO we are grateful for their transparency and from multiple public documents their aggregate number of machines deduced from their total hashrate and the efficiency of their hardware.

### *DragonMint T1:*

25,000 - 3/10

We have low confidence in this figure but we wanted to include an estimate nevertheless. There was a widespread need for a Bitmain competitor and in anticipating this, miners bought up all of the Halong mining products unseen and with a minimum order size of 5 units. At such a small batch size estimate the figure has minimal impact on overall calculations.

### *Innosilicon T2 Turbo:*

10,000 - 3/10

As with the other smaller companies it is very hard to gather much information to make a reliable estimate as to the number of miners out there.

### *MicroBT's Whatsminer M10:*

25,000 - 3/10

This is a difficult estimate for the same reasons as above. However, the efficiency of this miner is very impressive for its release date and there is significant forum support. Therefore, we have assumed they have put out a maximum output due to the community response.

### Hashrates and Power Efficiency per Unit

All except GMO Mining - 9/10

This represents a tempered belief in the state of the producers which will have modified only slightly if we believe the real-life specs are different (e.g. reading published reviews or forum reviews of trusted members acknowledging there to be a large disparity between the advertised spec and the testing spec).

GMO Mining - Hashrates taken from company filings [63].

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