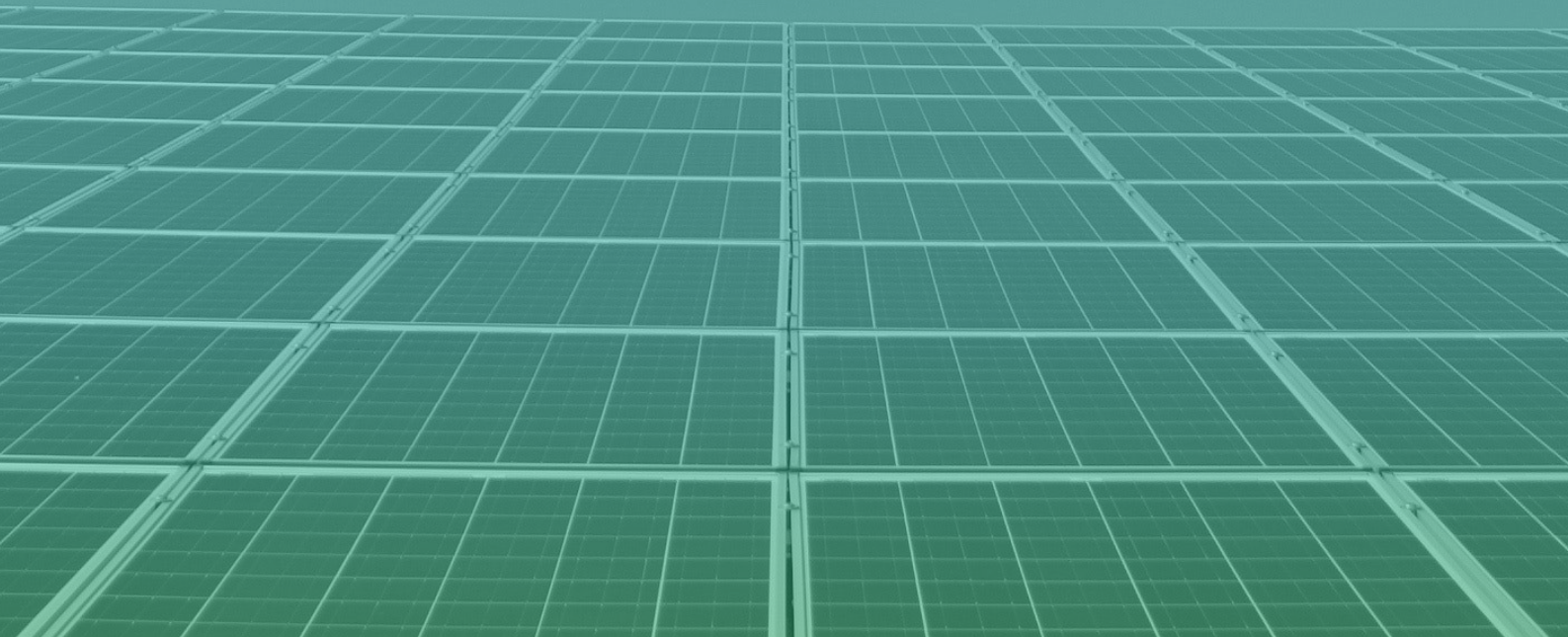


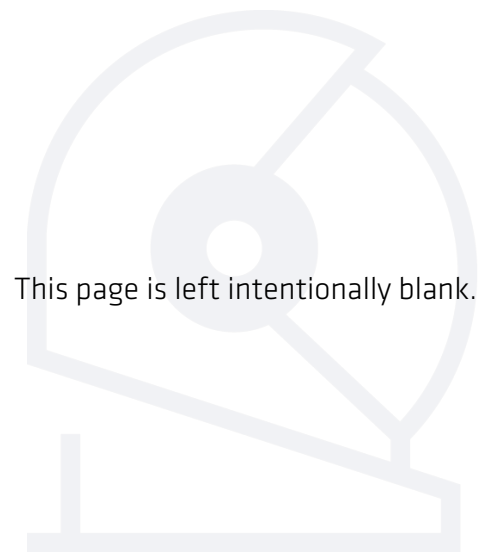


# THE BITCOIN MINING NETWORK

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

**NOVEMBER 2018 UPDATE**





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# The Bitcoin Mining Network

- Trends, Composition, Marginal 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 May, the market-average, all-in marginal cost of creation, at €5/KWh, and 18-month depreciation schedules has increased from approximately \$6,500 to approximately \$6,800. This suggests that, at current prices, the average miner is either: running at a loss and unable to recover capex, mining at electricity costs closer to €3/KWh, depreciating mining gear over 24-30 months, or paying less for mining gear than our estimates. Furthermore, we show that Bitcoin mining is mainly located in global regions where there are large, unused supplies of renewable electricity available. And finally, we calculate a highly conservative estimate of the lower bound of renewables in the energy mix powering the Bitcoin mining network at 77.6%, making Bitcoin mining greener than almost every other large-scale industry in the world.

## Introduction & Recap

In this second iteration of our bi-annual mining report we continue our ongoing observations and analysis regarding the state of the Bitcoin mining network. For a brief introduction on mining, its function and explanation of our network modelling methodology we refer to our previous paper published in May 2018 [1]. We continue to stress the importance of a strong mining network—utilising as much energy as the market is willing to allocate it—as an essential safeguard of Bitcoin’s trustless properties

Out of all currently deployed consensus algorithms, Proof-of-Work achieves the highest degree of trust-minimisation [2]. Under PoW, any user can verify for themselves that the current state of the UTXO Database is indeed correct as computed by the valid chain containing the most accumulated work (hereafter *the longest chain*). The amount of work accumulated in any given

chain is cryptographically and thermodynamically provable and the validity of the longest chain therefore needs no corroboration by anyone. This has not been proven possible under any other non-PoW consensus mechanism, all of which rely on some form of trust in current or previous network insiders.

We keep stressing these facts because the common public narrative surrounding the environmental impact of cryptocurrency mining is overwhelmingly negative. In order to produce PoW in a highly competitive market, cryptocurrency mining operations have so far consumed ever-increasing amounts of electrical energy. One reputable publication even made the groundless claim that the eventual impact of increasing carbon dioxide emissions from Bitcoin mining alone could lead to a two degree increase in global temperatures [3].

We believe these assertions are based on an inadequate understanding of the Bitcoin protocol and mining network. Furthermore, we suspect that they arise from a belief that mining Bitcoin is a pointless endeavour which generates negative externalities—of which environmental impact is one—with little real economic benefit.

Our view is that cryptocurrency mining—while costly—is doing little meaningful harm as far as the environment is concerned, and is also unlikely to do so in the foreseeable future. We also believe the benefits of a global, censorship-resistant, highly transferrable money with a rock-solid monetary policy behind it is worth that cost.

In fact, we continue to argue that Bitcoin mining could even be subsidising the development of renewable energy generation, thanks to the ability of mining facilities to move their operations to wherever the cheapest—and likely under-utilised—electricity is available.

#### Network development and marginal cost

Since our last report of May 2018, the hashrate has increased from approximately 30 EH/s to approximately 40 EH/s. During this period the Hashrate grew faster than the two-year average [Figure 3], but slower than the all-time average.

Over the same time, the price of bitcoin has fallen from around \$8,500 to around \$4,000. This has certainly put pressure on many miners as revenues have fallen while the difficulty has significantly increased.

The second half of 2018 has also seen the introduction of several next-generation mining units with significant improvements in both GH/J efficiency and investment cost per TH/s. On average, the efficiency of hardware introduced since our last report has fallen pretty much exactly along the previous trendline [Figure 1]. The cost of the hardware however, has on average fallen below the previous trendline [Figure 2].

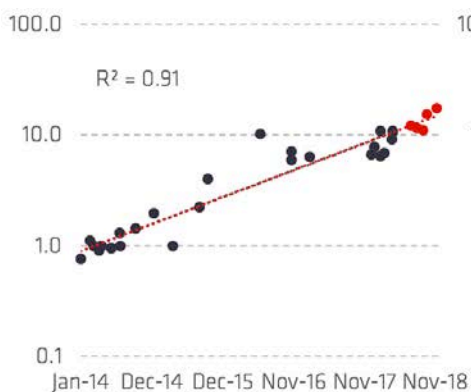
Our previously estimated market-average cost of production at €5/KWh and 18-month capex depreciation now stands at approximately \$8,500 versus \$6,500 in May [Table 3]. Against the backdrop of no reduction in global hashrate we take this to mean that the average miner is either: running at a loss and unable to recover capex, mining at electricity prices closer to €3/KWh, depreciating mining gear over 24-30 months, or paying less for mining gear than our estimates [Tables 1-5].

As is also evident from Tables 1-5, it is still very much possible to profitably mine under the right combination of electricity price, entrance point on the technology curve, and hardware cost.

For a full review of our modelling methodology we direct you to our previous report [1]. For a full overview of assumptions, please consult the appendix.

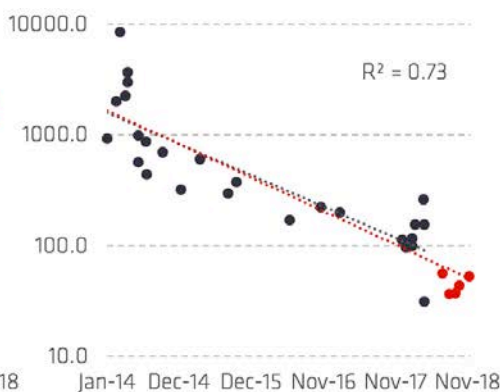
Another interesting observation is the trend of miners leaving China. When surveying the combination of publicly available literature [4] [5] [6] [7] [8] [9] and insight from industry insiders, it

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



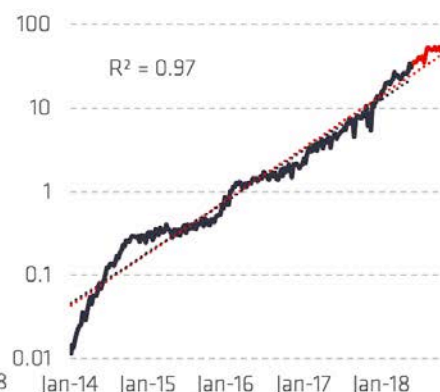
Sources: Bitcoin Wiki, CoinShares Research

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



Sources: Bitcoin Wiki, CoinShares Research

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



Sources: blockchain.com, CoinShares Research

Table 1: Market-Wide Creation Cost (US\$/BTC) at 30% C&O OPEX and -20% Below Standard CAPEX Assumption

-20% CAPEX		CAPEX Horizon (Depreciation Schedule)				
+30% C&O OPEX		30 Months	24 Months	18 Months	12 Months	6 Months
Electricity OPEX						
0.01 \$/kWh		2,311	2,718	3,397	4,756	8,831
0.03 \$/kWh		3,672	4,079	4,759	6,117	10,192
0.05 \$/kWh		5,033	5,441	6,120	7,478	11,554
0.07 \$/kWh		6,394	6,802	7,481	8,839	12,915
0.09 \$/kWh		7,755	8,163	8,842	10,201	14,276

Source: CoinShares Research

Table 2: Market-Wide Creation Cost (US\$/BTC) at 30% C&O OPEX and -10% Below Standard CAPEX Assumption

-10 CAPEX		CAPEX Horizon (Depreciation Schedule)				
+30% C&O OPEX		30 Months	24 Months	18 Months	12 Months	6 Months
Electricity OPEX						
0.01 \$/kWh		2,515	2,973	3,737	5,265	9,850
0.03 \$/kWh		3,876	4,334	5,098	6,627	11,211
0.05 \$/kWh		5,237	5,695	6,459	7,988	12,573
0.07 \$/kWh		6,598	7,056	7,821	9,349	13,934
0.09 \$/kWh		7,959	8,418	9,182	10,710	15,295

Source: CoinShares Research

Table 3: Market-Wide Creation Cost (US\$/BTC) at 30% C&O OPEX at the Standard CAPEX Assumption

Standard CAPEX Assumption		CAPEX Horizon (Depreciation Schedule)				
+30% C&O OPEX		30 Months	24 Months	18 Months	12 Months	6 Months
Electricity OPEX						
0.01 \$/kWh		2,718	3,228	4,077	5,775	10,869
0.03 \$/kWh		4,079	4,589	5,438	7,136	12,230
0.05 \$/kWh		5,441	5,950	6,799	8,497	13,591
0.07 \$/kWh		6,802	7,311	8,160	9,858	14,953
0.09 \$/kWh		8,163	8,672	9,521	11,219	16,314

Source: CoinShares Research

Table 4: Market-Wide Creation Cost (US\$/BTC) at 30% C&O OPEX and +10% Above Standard CAPEX Assumption

+10 CAPEX		CAPEX Horizon (Depreciation Schedule)				
+30% C&O OPEX		30 Months	24 Months	18 Months	12 Months	6 Months
Electricity OPEX						
0.01 \$/kWh		2,922	3,482	4,416	6,284	11,888
0.03 \$/kWh		4,283	4,844	5,778	7,645	13,249
0.05 \$/kWh		5,644	6,205	7,139	9,007	14,610
0.07 \$/kWh		7,006	7,566	8,500	10,368	15,971
0.09 \$/kWh		8,367	8,927	9,861	11,729	17,333

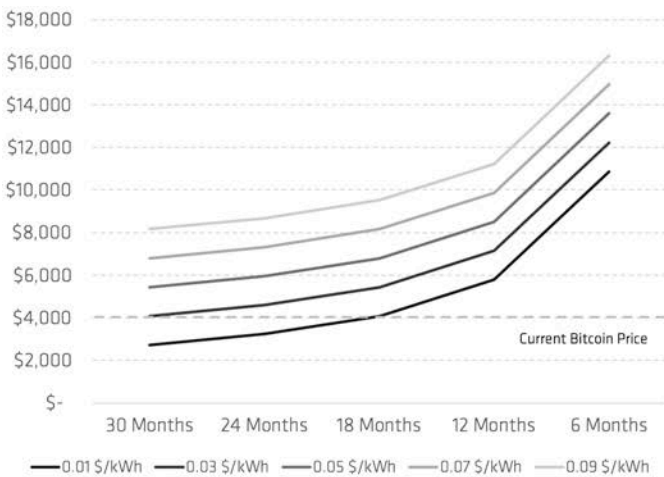
Source: CoinShares Research

Table 5: Market-Wide Creation Cost (US\$/BTC) at 30% C&O OPEX and +20% Above Standard CAPEX Assumption

+20 CAPEX		CAPEX Horizon (Depreciation Schedule)				
+30% C&O OPEX		30 Months	24 Months	18 Months	12 Months	6 Months
Electricity OPEX						
0.01 \$/kWh		3,126	3,737	4,756	6,794	12,907
0.03 \$/kWh		4,487	5,098	6,117	8,155	14,268
0.05 \$/kWh		5,848	6,459	7,478	9,516	15,629
0.07 \$/kWh		7,209	7,821	8,839	10,877	16,990
0.09 \$/kWh		8,570	9,182	10,201	12,238	18,351

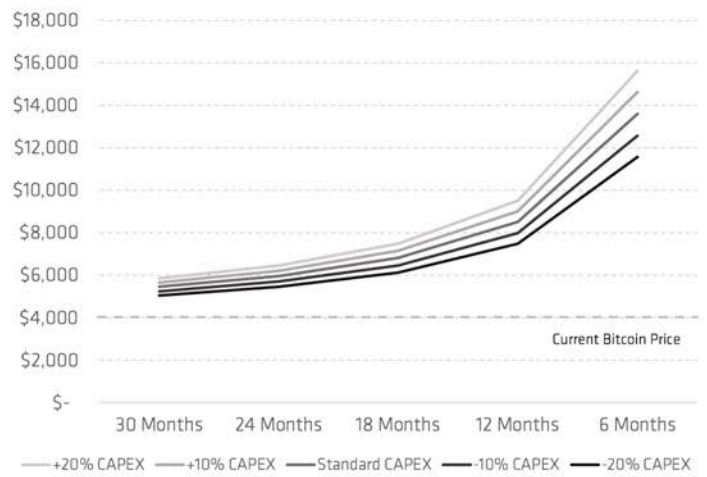
Source: CoinShares Research

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



Source: CoinShares Research

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



Source: CoinShares Research

is clear to us that miners are, in significant numbers, leaving China, or choosing not to reinvest within China. Instead, they are setting up operations in certain regions of Scandinavia, Russia, Canada and the United States where the combination of cheap abundant electricity, friendlier regulation, fast internet connections and, to a lesser degree, cooler climates can be attained [5] [6] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32].

*Quantifying the amount of renewable energy used in the Bitcoin mining industry*

It is commonly believed that most Bitcoin mining still takes place in China. While we cautiously agree with this belief, our estimate is that no more than 60% of hash power currently remain within Chinese borders. We therefore focus mainly on China in our analysis where we reference electricity generation data by province and cross-reference wherever possible to the publicly disclosed figures of listed renewable generation operators.

The structure of our argument—which is a continuation of the hypothesis offered in our previous work—is as follows: An analysis of the energy mix by region—in China’s case by province—cross-referenced with provincial curtailment data, should offer insight into the most likely source of electricity supply for these miners by region. What we seek to demonstrate is that a

large majority of Chinese Bitcoin mining is run on renewable energy which was formerly rejected by GRIDS grids due to oversupply, known as curtailment.

Chinese miners are mainly situated in a handful of provinces: Sichuan—where we estimate 80% of Chinese miners are located—Yunnan, Guizhou, Tibet, Xinjiang, Western Inner Mongolia and Heilongjiang [Figure 6].

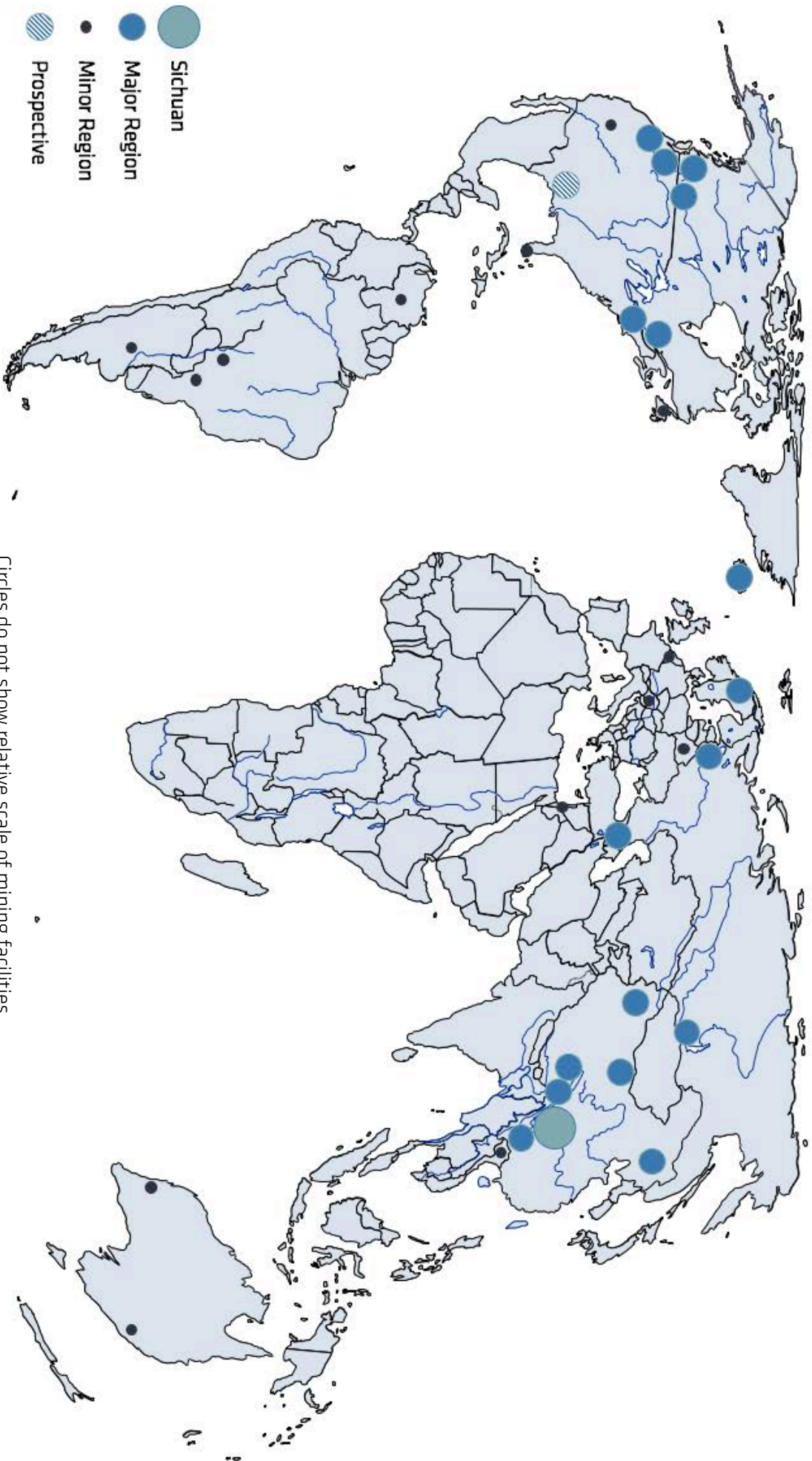
These locations are not chosen at random. The key consideration driving the location decision for these miners is the presence of low-cost electricity, high-speed internet, and in the case of the Northern regions, low temperatures that reduce the need for additional cost of cooling [10].

While there is certainly some mining taking place outside of our regions of focus, these operations are currently not large enough to warrant detailed investigation.

*Curtailment: A long-standing issue for renewables*

A key issue for renewable energy generation over the past 10 years in China has curtailment. The impact of curtailment to the earnings of renewable generation operators is material: on a fixed cost base, depreciating the high initial investments, the curtailment of generation output has a magnified impact on net profitability—and hence sustainability—of these renewable generation operators.

Figure 6: Global Overview of Bitcoin Mining Regions: Regions With Large Relevant Miners Shown in Blue, Sichuan in Teal and Remaining Small-Scale Regions in Black



Circles do not show relative scale of mining facilities

[5] [6] [8] [9] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33]

For readers unfamiliar with curtailment, the term refers to the consequences of over-generation from renewable sources, where electricity which is produced is rejected by the grid for fear of overloading and risk of a grid shutdown. The primary cause of curtailment stems from the over-investment—and subsequent overcapacity—in renewable generation capacity by the Chinese government, which saw large swathes of renewable generation capacity (mainly wind and solar) in areas with high generation potential but low local populations, mostly on the frontiers of China’s northern and western borders.

Curtailment rates by region have previously reached highs of more than 30% [Table 6, Table 7], creating a substantial hurdle for the investability and profitability of renewable energy projects. The government has been heavily subsidising the renewables sector in China, already to the tune of a \$25 billion deficit in the state's renewables fund [34]. In order for the sector to continue growing, standalone profitability, rather than reliance on government subsidies, must be established in a sustainable and permanent manner.

Across the three major forms of renewable energy, data on curtailment is most readily available for wind generation, followed by a handful of numbers for solar, and close to nothing publicly available on hydro. This is largely a function of the number of operators that are publicly listed and hence have verifiable and publicly disclosed data.

Table 7: Chinese Solar Curtailment by Province

Province	Year			
	2015	2016	2017	1H2018
Shanxi		6.9%	13.0%	7.8%
Gansu	31.0%	30.5%	20.8%	11.0%
Qinghai		8.3%	6.2%	3.2%
Ningxia	26%	7.2%	6.4%	4.1%
Xinjiang		32.2%	22.0%	19.7%
<b>Nationwide Overall</b>		<b>10.3%</b>	<b>6.0%</b>	<b>3.6%</b>

Sources: Deutsche Bank Research, Chinese National Energy Agency

Curtailment data on hydroelectric generation is unavailable, although publicly available news articles provide enough data on the location of major hydroelectric dam projects in China to construct Table 8 (next page).

A cursory look at the combined data leads to an observation which is cannot simply be explained by coincidence: the bulk of Chinese Bitcoin mining is located in provinces where either wind/solar curtailment is high, or where total installed hydropower capacity is large.

#### *Quantifying the amount of renewable energy used in Chinese mining*

It is clearly not by chance that miners choose to locate themselves in areas where electricity supply is in surplus. Cheap electricity, especially electricity that would otherwise be wasted, is

Table 6: Chinese Wind Curtailment by Province

Province	Year				
	2011	2012	2013	2014	2015
Hebei	4.0%	12.5%	16.6%	12.0%	10.0%
Shanxi	0.0%	0.60%	0.0%	0.0%	2.0%
West Inner Mongolia	23.2%	26.0%	12.2%	9.0%	18.0%
East Inner Mongolia	25.3%	34.3%	19.5%	9.0%	18.0%
Liaoning	9.0%	12.5%	5.0%	6.0%	10.0%
Jilin	14.9%	32.2%	21.8%	15.0%	32.0%
Heilongjiang	14.5%	17.4%	14.6%	12.0%	21.0%
Gansu	27.4%	24.3%	20.7%	11.0%	21.0%
Xinjiang	3.2%	4.3%	5.2%	15.0%	32.0%
Yunnan	0.0%	6.0%	3.7%	4.0%	3.0%
<b>Nationwide Overall</b>	<b>16.2%</b>	<b>17.1%</b>	<b>10.5%</b>	<b>8.0%</b>	<b>15.0%</b>

Sources: Deutsche Bank Research, Chinese National Energy Agency



essential for miners given the significance of electricity costs as part of their total cost of mining (we estimate just below 50% at 18-month depreciation schedules, more if longer).

While we are unable to pin down the percentage of renewable vs non-renewable energy use for individual mining operations, we can make educated guesses based on the policy targets for renewable vs non-renewable use laid out in the latest Renewable Portfolio Standard (RPS) requirements laid out by the Chinese government.

The following are estimates put together by the utilities research team at Morgan Stanley (Credit to Simon Lee and Eva Hou):

Table 8: Chinese Renewables Penetration by Province

Relevant Chinese Provinces	Est. Renewables Penetration (2018)
Sichuan	90%
Yunnan	92%
Guizhou	40%
Tibet	98%
Inner Mongolia	16%
Heilongjiang	15%
Xinjiang	23%
<b>Average ex. Sichuan</b>	<b>47%</b>

Source: Morgan Stanley Research

The correlation is crystal clear: the very provinces that house the majority of cryptocurrency mining operations in China are also the ones that derive sizeable proportions of their energy generation mix from renewables (see full table in the Appendix).

For example, in Sichuan where an estimated 80% of Chinese Bitcoin mining is located (48% of global), 90% of the total energy mix is renewable in 2017, and it would be reasonable to assume, given the impossibility of confirming on an individual miner basis, that the energy mix most miners face on the provincial wholesale market would be at least renewable to a similar extent.

Using the figures above, we can then reasonably estimate that 43.2% of global Bitcoin mining is powered by renewables in Sichuan. We can then take the average renewables mix of the six

provinces where the remaining 20% of Chinese Bitcoin mining (12% of global) is located and calculate their contribution to the total global mining energy mix to be 5.7% renewables and 6.3% fossil/nuclear [Table 10, next page].

*Quantifying the amount of renewable energy used in Western mining*

Outside of China, relevant large-scale Bitcoin mines are mainly located in the Pacific North West (Washington State, Oregon and British Columbia), Quebec, upstate New York, Northern Scandinavia (Norway and Sweden), Iceland and Georgia. The energy sectors of almost all of these regions except New York and Russia are dominated by renewables and there are publicly available figures showing the percentage of renewables penetration in each region [Figure 9]. Europe and North America also have the lowest hydropower utilisation factors in the world, with both regions using less than 40% of installed capacity [35].

Table 9: Western Renewables Penetration by Country State or Province

Relevant Western Countries/States/Provinces	Renewables Penetration (2016)
Washington	92%
Oregon	100%
New York	45%
British Columbia	98%
Quebec	100%
Norway	99%
Sweden	65%
Iceland	100%
Russia	17%
Georgia	79%
<b>Average</b>	<b>79%</b>

**Rest of the World 18.2%**

Source: EIA

Here, too, it is no accident that miners have chosen to set up shop in regions with known overabundance of cheap renewables—mainly hydro—such as Washington, Oregon, Norway and Quebec. While we suspect the same be the case for miners in New York and Russia, and there is evidence to support this [10] [27], we still consider it prudent to assume the worst possible

energy mix for these regions in the name of conservatism.

While there is no way of unilaterally proving what sources of power the individual non-Chinese miners use, it is again reasonable to assume that they on average use no less than the regional averages. Let us then accept the common view that 40% of all mining is undertaken outside of China and that 35% of those 40% are in the relevant regions discussed above. We then assume that mining is evenly distributed—which is not true, but is useful as an approximation of a lower bound. We can then take the average of the relevant energy mix which is renewably produced (79%) in these regions to reasonably estimate that out of the 35% of Bitcoin mining occurring in the relevant west, a minimum of 27.8% is powered by renewables.

The remaining 5% of global mining is assumed to be globally evenly distributed and subject to the global renewable energy penetration of 18.2%, adding 0.9% to the renewables, and 4.1% to the fossil/nuclear components of the energy mix.

The combined figure gives a lower bound of 77.6% total renewables in Bitcoin’s global electricity mix and an upper bound of 22.4% fossil/nuclear. A far cry from previously reported, but entirely unsubstantiated claims calculated by poorly designed methodologies [36].

It is therefore our belief that the claims around the environmental damage caused by cryptocurrency mining fundamentally miss out on the fact that many miners, in their self-serving search for the most cost-efficient form of electricity, have zoomed in on global regions with a glut of renewable electricity as prime locations for mining.

This is in stark contrast to the common

assumptions cited in the media on Bitcoin mining emissions and subsequent impact on the environment, whose argumentation presupposes exponentially accelerating requirements for electricity—a fundamental misunderstanding of the mining process—and that the incremental supply is going to be powered by traditional energy sources like coal—which is wrong.

While we have seen some studies coming tantalisingly close to using sound methodologies when estimating the carbon footprint of Bitcoin mining, even here the authors completely fail to take account of regional differences in the energy mix [37].

#### *Doing no harm vs doing good*

Cryptocurrency mining is likely to actually be consuming excess capacity on the grid, and even supporting the profitability and as a consequence the development of renewable energy generation capacity. While we can say with reasonable certainty that cryptocurrency mining is at the very least not doing any incremental harm—by taking up electricity that would otherwise be grounded and wasted—proving that it is actually net beneficial for the renewables space is a bigger challenge warranting deeper research in subsequent work.

It is however interesting to consider the following thought:

Could the rise of cryptocurrency mining actually be a highly desirable prospect for the renewables industry? It is obvious that running fibre is cheaper than building UHV grids. The extreme mobility and low manpower requirements of mining gear compared to its total power draw therefore makes it ideal for directly monetising

Table 10: 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	48.0%	90.1%	43.2%	4.8%
Relevant Remaining China	12.0%	47.1%	5.7%	6.3%
Relevant Western Regions	35.0%	79.4%	27.8%	7.2%
Rest of World	5.0%	18.2%	0.9%	4.2%
<b>Global Total</b>	<b>100%</b>		<b>77.6%</b>	<b>22.4%</b>

Sources: Deutsche Bank Research, Chinese National Energy Agency, Morgan Stanley Research, EIA, CoinShares Research

remote or stranded renewables, increasing the profitability of such projects.

We can also not forget that mining secures consensus on the transaction ordering of a monetary network containing ~US\$80bn worth of assets.

While we find the notion of attacking a value-creating industry based on its consumption of electricity freely purchased by willing sellers in the open market rather absurd, if one nevertheless was to embark on such a spurious line of argumentation we humbly suggest efforts might be better directed towards other applications of electricity:

For example, there are approximately 85m PlayStation4, 40m Xbox One and 15m Nintendo Wii U consoles distributed among global households [38] [39] [40]. Their weighted average gameplay power draw is approximately 120W. Assuming they are played on a modern 40" LED TV drawing only 40W, for 4 hours a day, and idling for 20 hours a day, at a weighted average of 10W, these gaming systems *alone* draw more power (4.9GW) than the entire Bitcoin mining network (4.7GW).

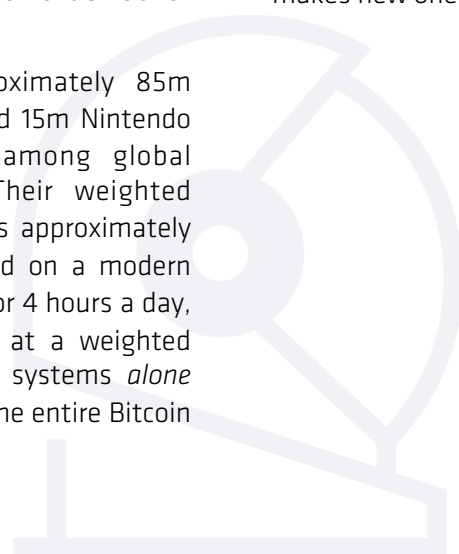
### *Conclusion*

Based on historical data on energy mix and locations of cryptocurrency mining operations in China, we have shown that contrary to the common narrative, the vast majority of global Bitcoin mining capacity (minimum 77.6%) is running on renewable energy.

The coincidence of high renewables penetration and the location of Bitcoin mining operations cannot not be dismissed as chance. While current data on a still-nascent industry is lacking, further studies may yet prove that, at least in terms of the environment, not only does cryptocurrency do no harm, it could actually be doing good.

Bitcoin mining may in fact be acting as an electricity buyer of last resort [41], creating a highly mobile base-demand for any electricity sources able to produce at prices below current producers, regardless of location. If demand for Bitcoin mining keeps increasing, its demand alone could facilitate opportunities for tapping highly productive renewables locations in areas that today would be uneconomically remote.

Building on a framework conceived by Nic Carter we can visualise this idea by thinking of the global energy network as a 3D topographical map of the world carved into a table. Cheap energy areas are lower while expensive energy areas are higher. Traditional residential and industry demand can be thought of as blocks nailed to the map, only able to move with considerable effort. Bitcoin mining on the other hand, due to its high mobility, is more akin to a glass of water poured over the surface of the map, settling in the grooves, smoothing it out. This effect “liberates stranded [electricity generation] assets and makes new ones viable”[41].



## Appendix

### *Specific Assumptions*

(CoinShares Research Assumption Rating Strength from 0 – 10)

### Mining Unit Cost in US\$

All unit prices are attempts at volume weighted averages across the entire hardware life cycle.

These assumptions are broadly based on the same information as those in our May report. Wherever updates were necessary, explanations have been added in brackets below the original assumptions.

### *Bitfily:*

US\$ 899 – 8/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [38]. 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.

### *Bitfury Block Box:*

US\$ 1,300,000 – 6/10

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 [39] 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 optimize and even reconfigure in operation.

### *Bitfury x Hut 8:*

US\$ 1,300,000 – 6/10

See above assumption for privately sold Bitfury units.

### *Antminer S9 Publicly Available Units:*

US\$ 1,100 – 7/10

This price is a function of several variables proprietary to Bitmain. One of the most pronounced observable ones is the bitcoin price. While the price has swung greatly over the time of our available data and monthly sales are not available, we consider this price to be our best guess at a volume weighted average.

We have compiled a table of the S9 price and the bitcoin price over the last seven months and, although the dataset is small, it is easy to observe that the bitcoin price alone does not set the price. Bitmain has been considered a somewhat infamous and divisive figure, especially in western sources, being actively involved in various efforts that many consider to be detrimental to Bitcoin (Bitcoin Cash, SegWit2x etc.). Considering that reputation and the timeframe, there is some reason to believe that

Bitmain was in fact pricing the S9 according to attempts from other players to enter the market. During this period, where the price is marked heavily marked down, Halong Mining were taking their first round of orders for their Dragonmint Miner “T1” and Ebang Technologies and Canaan mining were taking orders for their latest developments towards the end of the timeframe. The hypothesis would be that they were trying to influence the market—as has been levelled against them multiple times—in an attempt to suppress the competition.

The reason for the short time period is the fact that Bitmain only hosts old URL’s for batch prices for a short period of time and beyond that timeframe we would rely on forum literature which is hard to find. (Compare [40] with [41] where in the former you can no longer click through Bitmain’s link to a particular batch release and in the latter you are taken to a specified batch).

Table 11: Overview of Archived Batch Prices of the Bitmain S9 Mining Unit.

Batch	S9 Price	BTC Price
May 18	\$1,222	\$9,000
Feb 18	\$2,725	\$9,250
Jan 18	\$1,995	\$13,500
Dec 17	\$2,320	\$16,500
Nov 17	\$1,265	\$8,000
Oct 17	\$1,500	\$5,250
Sep 17	\$1,750	\$4,750
<b>Average price</b>	<b>\$1,825</b>	<b>\$9,464</b>

*[Update November 2018: Having spoken to a few large miners and researched extensively online we have discovered purchases made in bulk between 250 and 300 dollars. However, Bitmain does make a significant amount of its sales to smaller miners, specifically through its e-shop. The price on the shop is currently \$307 and \$294 for the respective ‘I’ and ‘J’ models. More recently the price has been hovering around the \$500 mark, and from reading Bitmain’s IPO prospectus it is clear they have been making the majority of their sales earlier in the year. Thus, we have taken the price to be about \$400 on average for this next leg of the year between May and November 2018. Considering the number of units sold has more*

*than doubled we are inclined to simply take the mean between 400 and 1800 which gives us our price of \$1,100. As with the last figure we are not entirely confident in this estimate and considering that the vast majority of the network are operating on some variant of the S9 and the mining industry is by no means transparent we don’t expect this to be entirely accurate. We do however believe this is the best attainable estimate.]*

*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?” [39].

*[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 “Just how profitable is Bitmain?” [39]. 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% [42]. We therefore assume the price to be the same as our previous estimate.]*

*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% [42]. We therefore assume the price to be the same as our previous estimate.]*

*Ebang E10:*

US\$ 1800 – 7/10

This is sourced from the BitcoinTalk overview of currently competitive hardware [38]. 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 [43].

*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 this as we believe there are not a lot of them around that second-hand market is heavily indicative of the actual price as there's little evidence of any large-scale miners using these. 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 [38]. 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 [38]. 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 publicly [44] 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 S9 Publicly Available Units:*

2,150,000\* – 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.

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

230,000 – 6/10

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) [45][46] and the hydropower of Sichuan and Yunnan in the rainy season (Southwest) [45]; and lastly that they have facilities like it elsewhere in China and the world (such as in Anhui and Newfoundland [20]).

*[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 [4] and we have therefore assumed no additional gear added.]*

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

20,000 – 4/10

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.

#### *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 [42].

#### *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 [42].

#### *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 [47] 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.

*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

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. 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 [5].

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\*Due to the recent drop in hashrate we have assumed 20% of all Bitmain S9s and Avalon 841s to have shut down.



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