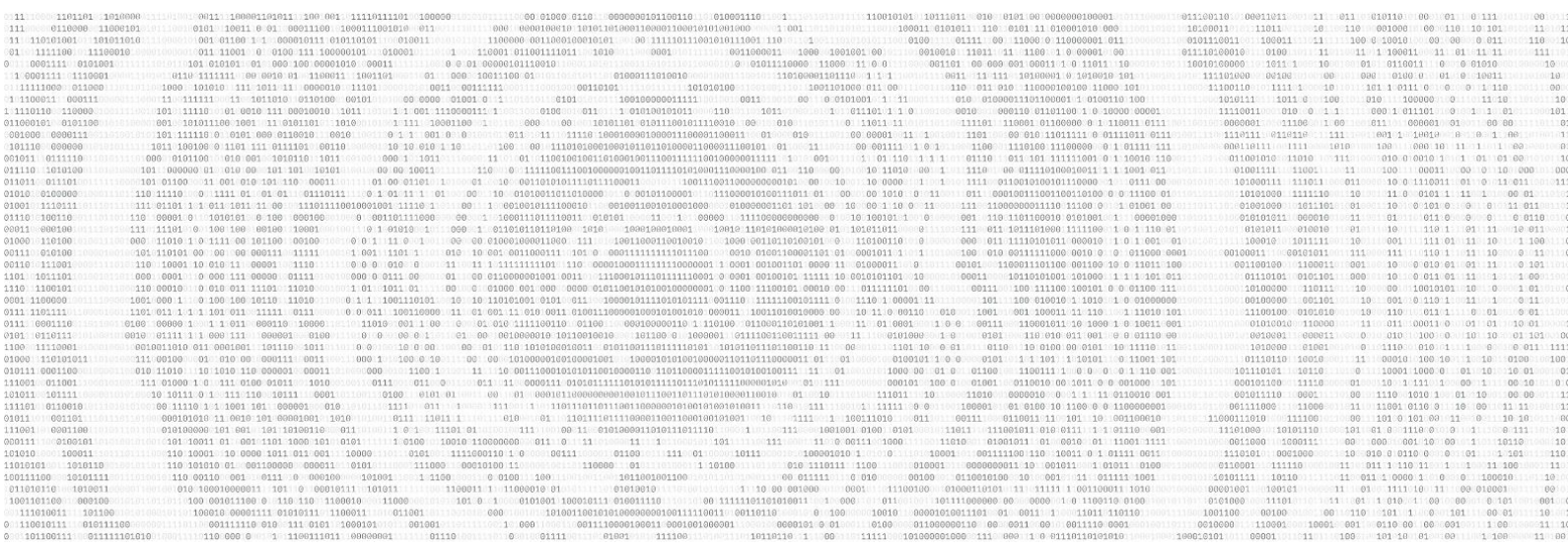
Cryptocurrency Mining Hardware

Striving for efficiency

Elwood Research Series
July 2020



Elwood Asset Management LLP

About Elwood Asset Management

Elwood Asset Management ("Elwood") is an investment firm specialising in providing investors exposure to digital assets and blockchain technologies.

The Elwood Blockchain Global Equity Index aims to offer exposure to listed companies that participate or have the potential to participate in the blockchain or cryptocurrency ecosystem. The index aims to capture the potential investment upside generated by earnings related to the adoption of blockchain technologies or cryptocurrency. It is designed to evolve with the future development of the blockchain space.

The index is independently calculated and distributed by Solactive and is reviewed and rebalanced quarterly.

Invesco has partnered with Elwood to launch an ETF and a Japan domestic mutual fund that aim to deliver the performance of the Elwood Blockchain Global Equity Index by physically investing in the index constituents.

Index

Ticker	Name
BLOCK Index	Elwood Blockchain Global Equity Index

ETF

Ticker	Exchange
BCHN LN	London Stock Exchange - USD
BCHS LN	London Stock Exchange - GBP
BNXG GY	Börse Frankfurt - EUR
BCHN IM	Borsa Italiana - USD
BCHE SW	SIX - USD

Investment Fund

Japan domestic mutual fund
Invesco World Blockchain Equity Fund

Contacts

www.elwoodam.com

block@elwoodam.com

twitter.com/Elwood_AM

Abstract

The idiosyncrasies of cryptocurrencies and mining operations demand sophisticated and efficient hardware. In that respect, Bitmain and MicroBT emerge as clear short-term winners. Canaan, one of the only two listed players in this space still has some catch-up to do if it intends to play in the same league, and the company has signalled that 5nm based equipment may be on the way for 2021, which could mean better machines in the future. In the meanwhile, we see a rather bleak outlook for the company and there could be significant pressure on equipment prices. Going up the supply chain, TSMC and Samsung dominate the chip supply and, although the two companies are very secretive about their operations in cryptocurrencies, we have estimated that this could be a billion dollar business, with significant impact in their revenues and profits.

Ticker	Company	Market Cap (US$m)	FY19 reported sales (US$m)	FY19 reported gross margin	FY19 reported EBIT margin
2330 TT	TSMC	278,590	34,646	46.1%	34.8%
005930 KS	Samsung	261,403	197,691	36.1%	12.1%
3443 TT	Global Unichip	1,150	346.8	33.0%	6.5%
CAN US	Canaan	297	204.3	(36.3%)	(74.1%)

(Source: Market Cap, Bloomberg, data as of 1 July 2020)

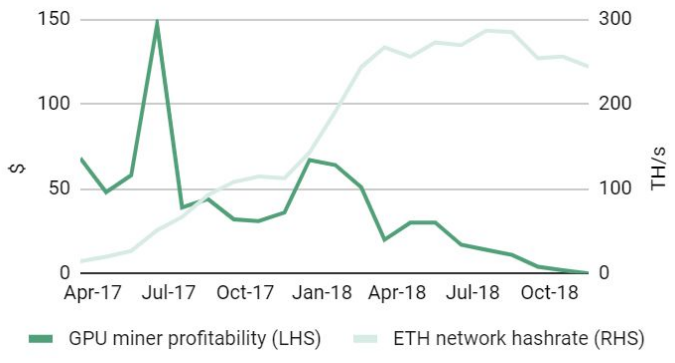
Evolution of mining hardware

GPU mining and early days

Cryptocurrency mining was previously done with graphics processing units (GPUs), commonly known as graphics cards. These chipsets provided very fast processing power, more specialised in parallel computing if compared to CPUs (central processing units). The world leading GPU designers and manufacturers have been Nvidia and AMD (post the ATI acquisition in 2006), maintaining a global dominance in this market up to this day.

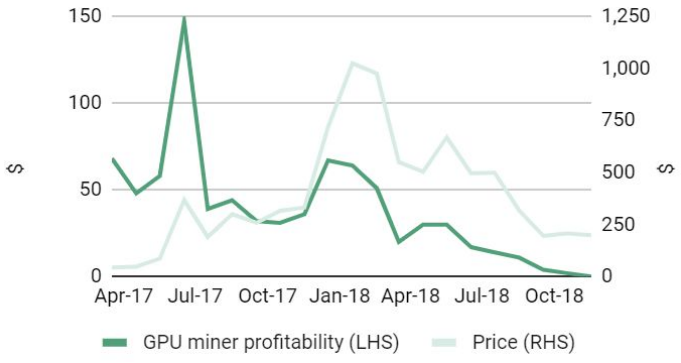
In the heyday of GPU cryptocurrency mining, Nvidia and AMD benefited significantly from mining. Between both manufacturers, revenue from mining-focused GPUs was approximately $500m in Q4 2017[1]. However, with the development of dedicated and faster ASIC (application-specific integrated circuit) miners, the use of GPUs in mining quickly reduced.

Monthly GPU profitability vs. Ethereum network hashrate



(Source: Elwood research, Etherscan)

Monthly GPU profitability vs. Ethereum price

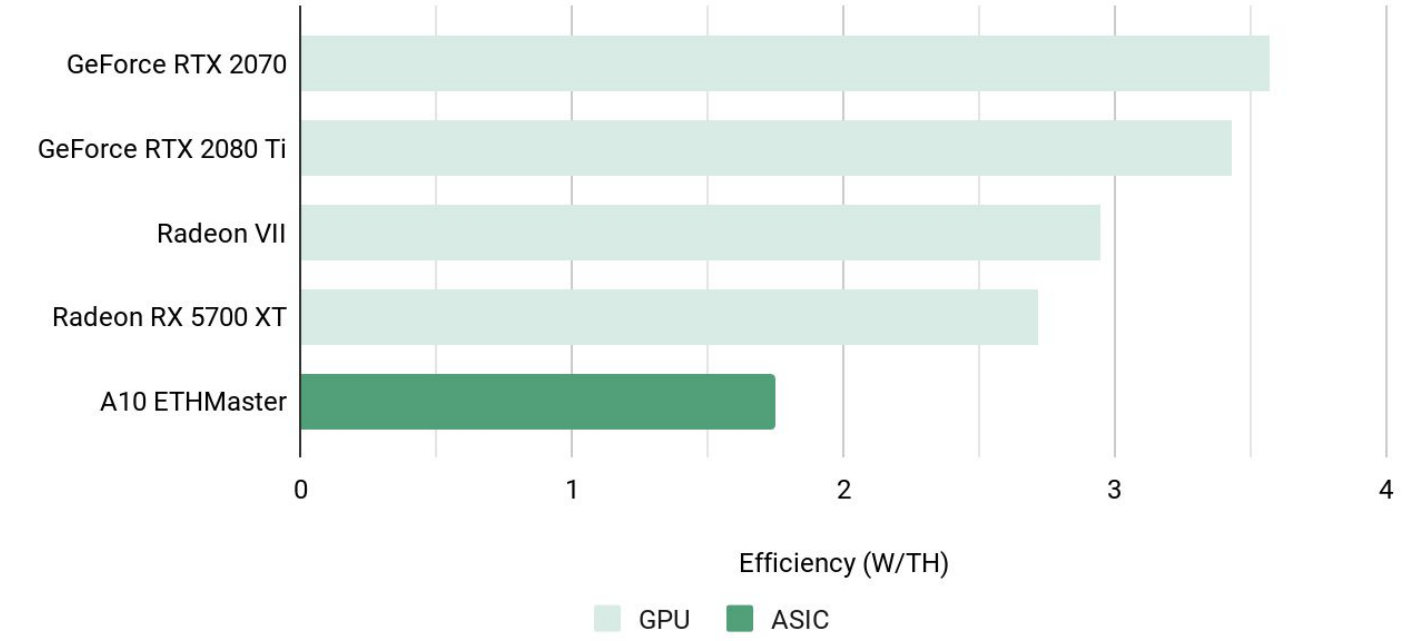


(Source: Elwood research, Etherscan)

[1] Source: Susquehanna [link]

When comparing ASIC miners versus GPUs, the benefits are not as clear as there is a deliberate effort to keep the network running on easily accessible hardware rather than purpose-specific mining hardware. Nonetheless, ASICs have managed to outperform GPUs.

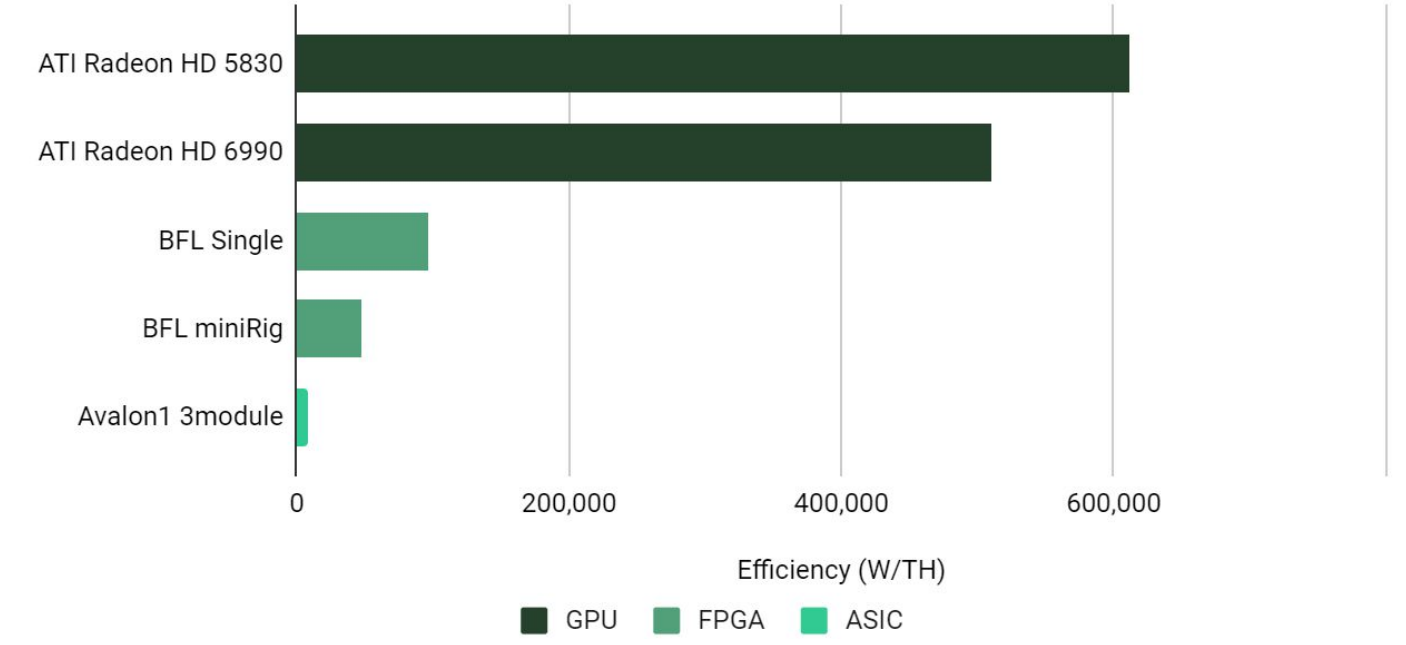
Efficiency: GPU vs. ASIC miners (Ethereum mining)



(Source: Elwood research)

The difference becomes more striking when comparing between GPU, FPGA and ASIC miners on the Bitcoin network. There is an order of magnitude's difference between each technology in favour of ASIC hardware. Between the release of the ATI Radeon HD 6990 in March 2011 and Canaan's Avalon1 3 Module in January 2013, efficiency improved from 510,000 W/TH to 8,333 W/TH.

Efficiency: GPU and FPGA vs. ASIC miners (Bitcoin mining)



(Source: Elwood research)

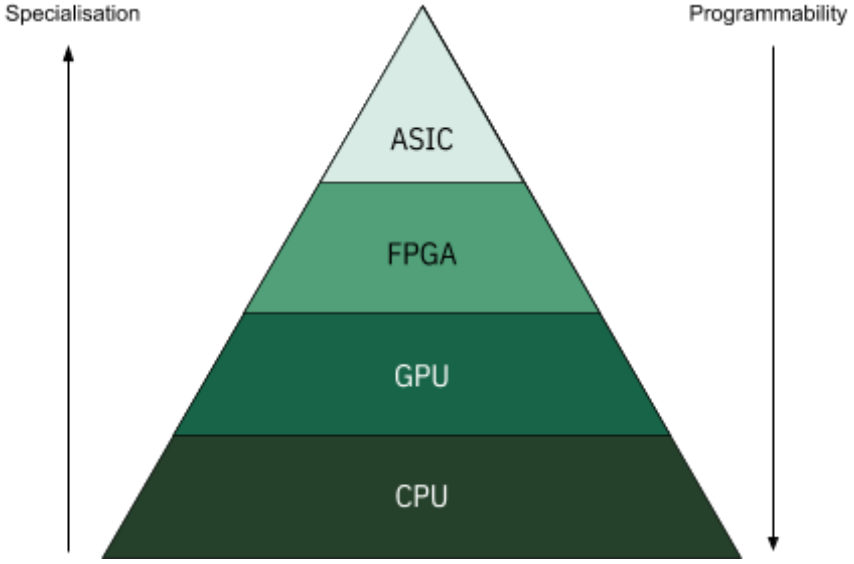
As a result, companies such as Nvidia and AMD stopped relying on sales from cryptocurrency mining entirely, as highlighted by the extract from Nvidia's Q4 FY19 results below, on 14 Feb 2019:

> *"For fiscal 2020, we expect Q1 to mark the bottom as we pass the inventory collection in Gaming. We expect total revenue for the year to be flat to down slightly with growth in our four end markets, compensating for the absence of crypto revenue and the excess sell-in from last year."*

ASIC mining and efficiency step-up

As the name suggests, ASICs are very specialised chips, designed and optimised for a single type of task. In comparison to other IC types, ASICs generally cannot be reprogrammed after being assembled. At the other end of the spectrum, CPUs can handle a large variety of tasks, which increases the applications where they can be used, but with lower efficiency and task optimisation as trade-offs.

Integrated circuits specialisation hierarchy



(Source: Elwood research)

The high degree of specialisation leads to several advantages and disadvantages in relation to other types of integrated circuits, namely:

ASIC advantages	ASIC disadvantages
Higher computing efficiency	Programming inflexibility
Size/layout optimisation	Longer development cycles
Less energy intensive	Higher production costs

As the above mentioned characteristics imply, ASICs lend themselves extremely well for power-intensive and homogenous tasks such as cryptocurrency mining. The pre-programmed chips are set up in machines, or miners, with cooling systems and basic I/O such as ethernet ports, so the miner can be connected to the broader network and accessed via a browser interface or terminal using its internet protocol (IP) address. Although they cannot be reconfigured or switched to mine a cryptocurrency using a different algorithm, basic settings usually allow operators to

adjust basic features, such as mining speed or switching to mine a different cryptocurrency using the same mining algorithm.

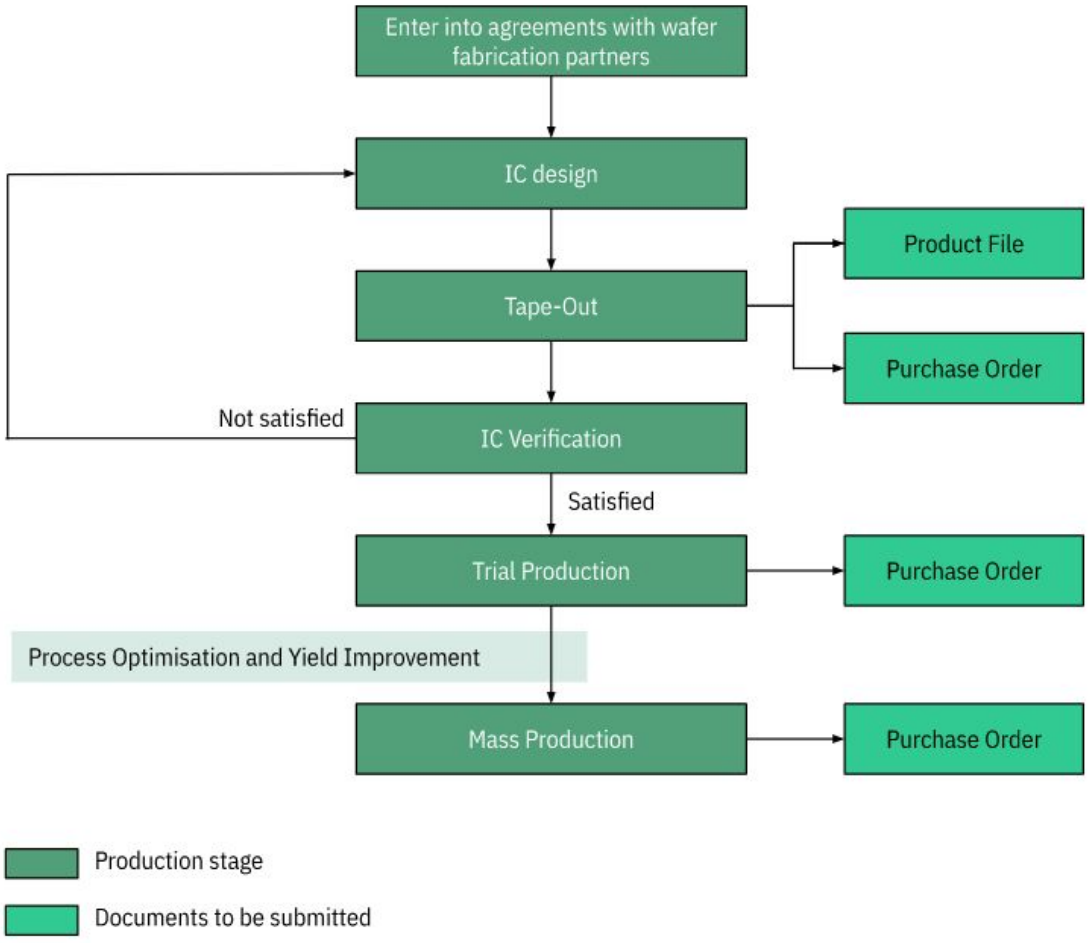
A key requirement for ASIC miners is algorithm stability - the non-programmable characteristics of this kind of integrated circuit means that updates and even slight changes to the mining algorithm could yield the device unusable, as the older, incompatible algorithm would not be able to solve the mathematical puzzles of newer or updated algorithm. This is also the case with some cryptocurrency forks, which could make miners obsolete for one of the new currencies or even both, depending on the situation.

Because of its market cap, ASICs are predominantly used to mine Bitcoin, on the SHA-256 algorithm, although other projects such as Ethereum, Litecoin and Zcash, among others, also use ASIC-based miners.

Production process

In this section we present the pipeline of a hardware production process, using Bitmain Technologies Ltd. as an example. Bitmain adopts a *fabless model*: ASIC chips for cryptocurrency mining hardware are not manufactured in-house, but produced in collaboration with partners throughout all the phases of the manufacturing process, including wafer fabrication, packaging and testing. Using this model, a company is able to leverage the expertise of industry leaders in different areas of the production pipeline, while internally focusing on few selected operations, e.g. research and development, product design and additional quality control.

Bitmain's fabless model: production process



(Source: Bitmain IPO prospectus)

The following are the main stages of the production process.

- **Chip design**: In this initial stage, the parameters of the chip and the basic logic design are established. The initial plan for the physical layout is mapped out, and a back-end verification on the design is conducted. The wafer foundry, which has the expertise in photomask making, finalises the layout. This stage generally ends with the tape-out, i.e. the graphic for the photomask of the chip is sent to the wafer foundry.
- **Wafer production**: Wafers for the ASIC chips are produced by a foundry. Design companies and foundries may enter into non-disclosure agreements to maintain intellectual property rights. The foundry receives the preliminary information about the chip design, and the layout is then finalised. Once the prototype is confirmed by the partner, the foundry initiates the mass production of the wafers. It takes, on average, three months for the delivery of the wafers once the orders are placed.
- **Packaging and testing**: After the wafers are manufactured, they are shipped to an OSAT company (Outsourced Semiconductor Assembly and Test) for packaging into ASIC chips, which are then tested to ensure that they meet all the quality control procedures. Order forecasts are generally provided 30 days in advance for OSAT companies to purchase necessary materials. Upon delivery, the purchaser has usually the right to request a refund for defective chips with a low packaging yield[2].
- **Procurement of other components**: In addition to proprietary ASIC chips, a mining hardware usually consists of other components, e.g. printed circuit boards (PCBs), auxiliary chips, fans, casings. Design companies may maintain more than one supplier for each component.
- **Assembly**: Next step is creating mounted circuit boards (PCB assembly) and integrating the circuit boards with other components to produce the final products (general assembly). Design companies may perform additional product testing at various stages of production and utilise proprietary software to record the testing results.
- **Warehousing**: Final quality check, packaging and product storage are carried out.

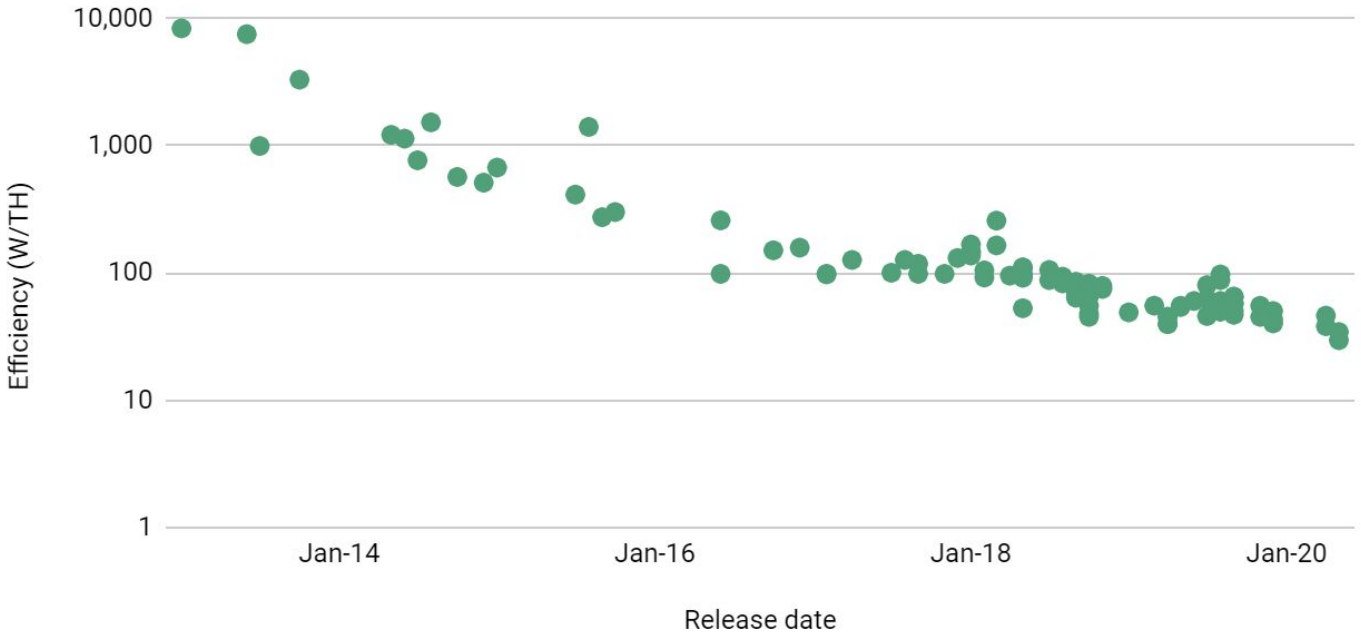
It's all about efficiency

As mentioned before, ASIC miners have a substantial efficiency advantage against other electronic devices. However, there are also considerable performance and efficiency differences between ASIC miners themselves. In cryptocurrency mining, efficiency is measured by the ratio between power consumption, measured in Watts, and the miner's hash rate, usually measured in Terahashes for bitcoin miners, resulting in a W/TH, or Watts per Terahash efficiency metric (for Ether miners, it is Watts per Megahash, or W/MH).

ASIC cryptocurrency miners have evolved considerably since the first models were rolled out by Canaan in 2013. Although radically more efficient than GPUs and FPGAs (field-programmable gate array), at 110 nanometres (nm), these chips used much more power than current hardware to execute the same tasks, with efficiency ratios well above 1000 W/TH for the early Canaan models, against 40 to 50W/TH in modern machines.

[2] The *packaging yield* is the ratio of the number of packaged components that pass the final electrical testing to the total number of components.

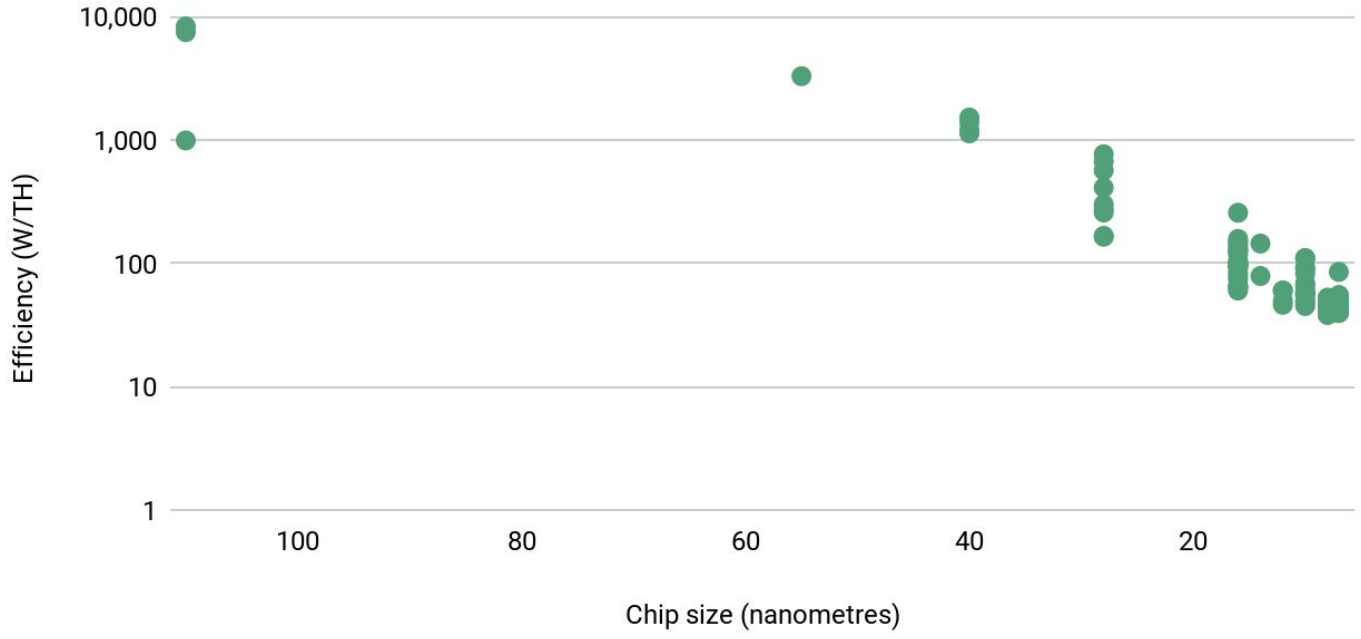
Cryptocurrency miner efficiency over time



(Source: Elwood research)

A number of factors have allowed the observed improvements in efficiency. The more quantifiable one is chip sizes. In the last few years, they have shrunk from 110nm in the early models, down to 7nm in the latest generation, and there is speculation that newer 5nm models may be on the way. However, as the chart below illustrates, chip size is not the only variable explaining different performances. We believe that chip design, packaging, cooling technology and other adjustments can also contribute to lower power consumption and increased performance.

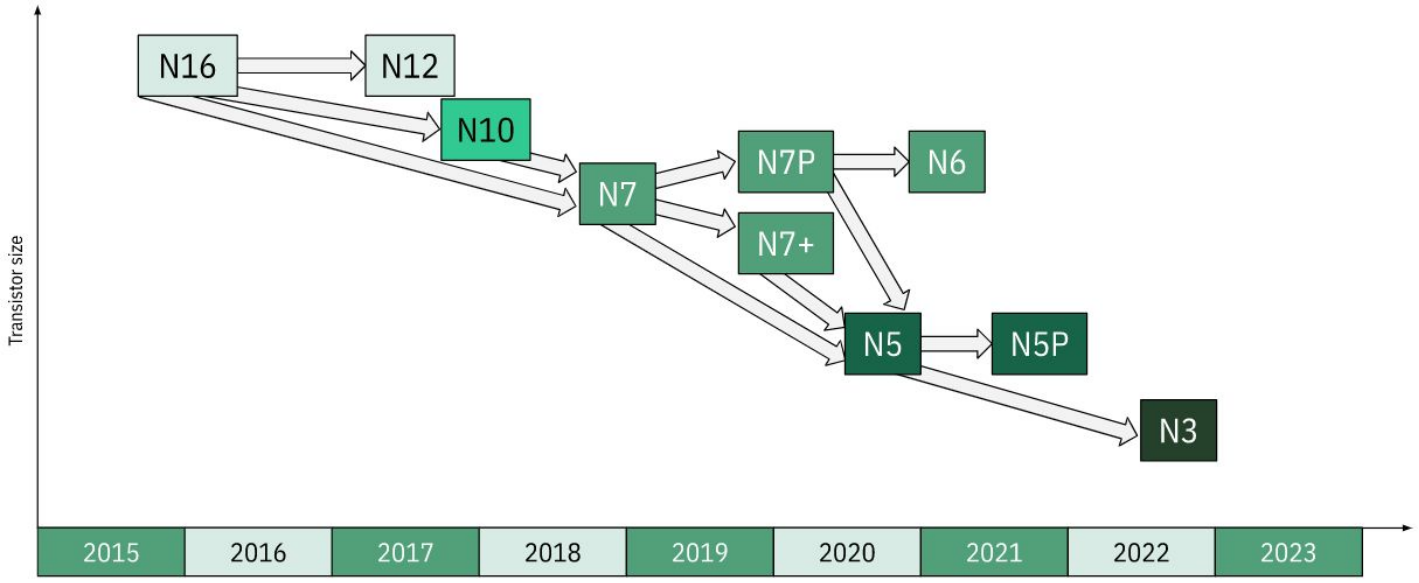
Cryptocurrency mining equipment efficiency vs. chip size



(Source: Elwood research)

We believe that 5nm miners could be well underway, given TSMC's chip roadmap presented last year and rumours that Bitmain and Canaan could be considering launching 5nm products already in 2020. These timelines have been certainly put into question due to the coronavirus pandemic, but the recent bitcoin halving and the continuous network difficulty increases will demand better and more efficient hardware.

TSMC logic node roadmap



(Source: TSMC, WikiChip)

During its calls throughout 2019, TSMC highlighted the importance of the development of new semiconductor technology. The company expects 6 nanometer chips (or N6 as labelled by the company) to have 15% to 20% higher logic density than N7 (7nm), while for N5 (5nm), TSMC expects logic density to be 1.8x as much as N7.

TSMC N5 chip improvement expectations against N7

Speed Improvement at Same Power	Power Reduction at Same Speed	Max Speed Improvement at Vdd (eLVT)	Logic Density (+2 metal layers)	SRAM Area Reduction	Analogue Area Reduction
~15%	~30%	~25%	~1.8x	~1.35x	~1.2x

(Source: TSMC)

Increasing difficulties and hash rates have also resulted in pressure for larger miners, although one could also argue that more powerful miners could have been the reason behind the very high network hash rates observed today. Regardless, at 70-100 GH, early miners had very limited processing power when compared to current mining hardware, which range between 50 and 80 TH, with various sizes available for operators to choose.

Bitcoin network hashrate

(Source: BTC.com)

Modeling cryptocurrency mining

In this section we show an attempt to model various types of cryptocurrency mining hardware in order to assess their profitability at different price levels, as well as break-even points by miner. We initially set out the variables we have used in our model, and then show the calculations and results in the following sections.

Model variables

While many believe that cryptocurrency prices and electricity costs are the only factors contributing to miner profitability, there are other variables that need to be taken into consideration. Among these are the overall network hashrate and difficulty, mining equipment hashrate, efficiency and mining pool fees.

Network hashrate and difficulty

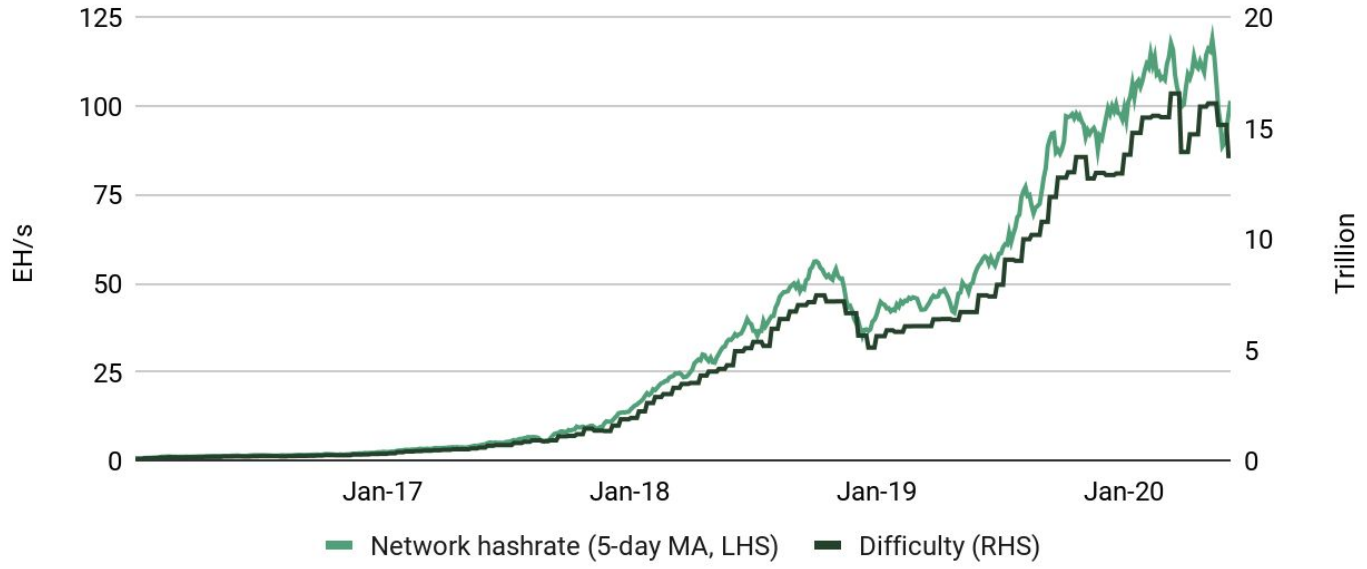
Network hashrate refers to the combined hashrate of all miners in a given network, which means that the higher the network hashrate, the higher the overall network effort to solve the mathematical puzzle aimed at adding a new block to the blockchain. The Bitcoin protocol has been designed to add a new block to the blockchain every 10 minutes, but, if the network hashrate spikes, it is likely that the time to add a new block will be lower than that. Conversely, if the network hashrate drops, then new blocks will be created in more than 10 minutes.

This is where *difficulty*, a measure of how difficult it is to mine a new block, comes into play[3]. The lower the target, the higher computational power requirements to find a new block are. As the network hashrate increases, the difficulty is adjusted upwards so that new blocks are again added every 10 minutes on average, and vice versa. In the Bitcoin

[3] Solving the mathematical puzzle is done by constructing a block of pending transactions, filling in additional metadata, and hashing the serialised datastream. If the resulting hash value is lower than the given target, represented by the difficulty measure, then the new block is successfully mined.

network, difficulty is adjusted every 2016 blocks or, using the 10 minutes average per block, this should translate into roughly once every 14 days.

Bitcoin network hashrate and difficulty



(Source: BTC.com)

Mining equipment hashrate

This measure relates to how many calculations per second a miner can make, measured in hashes per second (H/s). The higher an equipment's hashrate, the more calculations it can perform and the quicker it can solve the mining mathematical functions. Early ASIC miners could perform around 100 gigahashes, or 10^9 hashes per second (GH/s). This compares with current generation miners achieving nearly 100 terahashes, or 10^{12} hashes per second (TH/s). The increased computational power of current generation miners means that mining operators can achieve very high capacities at a reduced footprint, using less power and, consequently, higher efficiency rates.

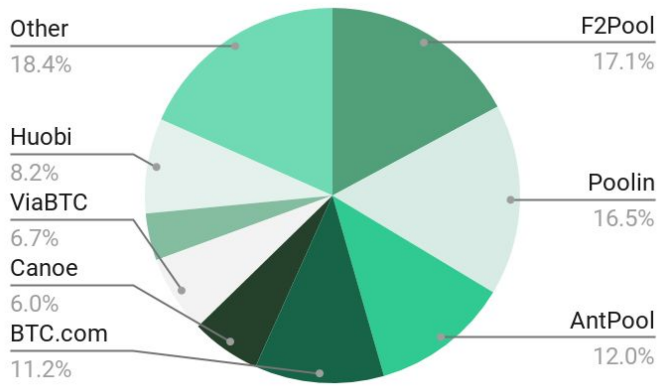
Efficiency

In this report, we refer to efficiency as a mining equipment's ability to perform calculations using a given amount of power. Efficiency can be measured as joules per hash, usually scaled up to gigajoules per hash (Gj/H), or the equivalent measure, watts per terahash (W/TH). In our view, efficiency is a crucial variable in miners' profitability and factors such as the latest Bitcoin halving meant that a number of older, less efficient equipment went out of market as they would not be profitable even at the most aggressive assumptions.

Mining pool fees

A cost element that usually gets overlooked is cryptocurrency mining pool fees. While it is possible to independently mine crypto assets, the miniscule computing power in relation to mining pools would likely result in unsuccessful attempts to mine new blocks. In order to achieve critical mass, miners organise themselves at pools that group together computing power (hash power) in order to increase their odds of fetching the next block and reduce the volatility of their earnings. Setting up a new pool that quickly reaches the scale of established larger operators is unlikely, which results in high barriers to entry. As a result, pool administrators retain some considerable pricing power and are able to charge fees varying from 2% to 4%. Below we show the largest mining pools as well as their mining fees.

Mining pool market shares



(Source: Elwood research)
Note: representative of the seven-day period leading up to 30 June 2020

Mining pool fee rates

Pool	Fee
F2Pool	2.5%
Poolin	4.0%
AntPool	2.5%
BTC.com	4.0%
Canoe	2.0%
ViaBTC	2.0% to 4%
OKEx	4.0%
Huobi	4.0%
Slush	2.0%
BTC top	2.5%

(Source: Elwood research)

Mining pool rewards

Another important consideration in cryptocurrency mining is how miner operators are paid out by pool administrators. These payouts are known as pool rewards and they can take different shapes. We detail the more common methods below:

- **Pay-per-share (PPS)**: miners are paid according to the number of valid shares contributed to the pool. Share value is calculated based on the theoretical amount of hash attempts needed to find one block, and vary according to changes in network difficulty. Pool members in the PPS method earn shares by providing hash power to the mining pool and have guaranteed payouts, regardless whether the pool finds a block or not.
- **Full pay-per-share (FPPS)**: this method is similar to PPS, but instead of paying miners only the block reward, the pool administrator adds a transaction fee that is paid by users making transactions on the block, and distributes it alongside the block reward according to each miner's share. This method results in higher payouts to pool participants.

Our model and assumptions

Using the variables above, we have created a cryptocurrency miner profitability model. Throughout this report, although we may mention other cryptocurrencies, we will keep our focus on Bitcoin, and all calculations below are based on Bitcoin. We have broken it down into two parts: revenue and costs.

Revenue calculation

To keep calculations concise, we have chosen PPS as our reward method. Additionally, our model does not take into account potential mismatches between difficulty and network hash rates, as discussed in previous sections. A further assumption has been made that mining pool's share among total hashrate is the same as its revenue share within the broader network.

Variable	Unit
Network hashrate	TH/s
Miner's hashrate	TH/s
Bitcoin price	$
Daily network revenue	$
Miner's share	%
Daily miner revenue	**$**

As a result of the assumptions above, in this model, miners receive the same proportion of revenues as their hashrate contribution within the network, i.e., if a miner has a hashrate of 100 TH/s and the network is running at 100 exahashes per second (EH/s, 10^{18} hashes per second), then the miner will be entitled to 0.0001% of the network's revenue at any given point.

Hence, in order to calculate the dollar revenues in our model, we take the miner's hashrate share within the network, multiply by the average number of blocks mined by the whole network during the day (1 every 10 minutes, or 144 during the day), multiply by the number of bitcoin awarded at each block (6.25 since May 2020) and finally multiply the amount by the Bitcoin price.

Cost calculation

The cost side of our model is made up of electricity costs and pool fees. Electricity costs are calculated by multiplying the miner's power consumption by the electricity charge, while pool fees are calculated as a percentage of total revenues generated by the miner on a given day or period.

Variable	Unit
Miner's hashrate	TH/s
Power consumption	W
Efficiency	W/TH
Electricity charge	$/kWh
Daily electricity cost	$
Pool fee	%
Daily mining profit	**$**

Summary

Based on the two subsections above, we can summarise the profitability model with the expression below:

$$DMP = 144 \times 6.25 \times (1 - f) \times \frac{m}{N} \times P - 24 \times m \times e \times E$$

Where:

DMP = Daily mining profit
m = Miner's hashrate
N = Network hashrate
P = (Bitcoin) price
f = Pool fee
e = Efficiency rate
E = Electricity charge

Modeling analysis

In this section we present the output for our analysis, based on the assumptions laid out above and each of the main equipment manufacturers data. We have shortlisted manufacturers that are still in business and that have released machines since 2017, as per below:

Manufacturer	Brand	Latest series
Bitmain	Antminer	S17
Bitfury	Bitfury	Tardis
Canaan	AvalonMiner	Series 10
MicroBT	Whatsminer	M20
Innosilicon	Innosilicon T	T3
Ebang	Ebit	E12

(Source: Elwood research)

Basic assumptions

Although there are several variables in the model, some of them are fairly similar across various operators. Electricity charges tend to be low due to the fact that cryptocurrency mining companies seek to choose jurisdictions that offer low electricity prices, such as Canada and the Nordic countries (see our previous note for further information), and in previous management calls we have been told that electricity costs range around US$0.03/kWh. Mining pools are fairly concentrated, with the top 10 largest providers accounting for nearly 90% of the mining hashing power. This has led to uniform fees being charged across the board, ranging between 2% and 4% of revenues.

Based on the assumptions above, on the average trading range of bitcoin over the last 12 months and network hash rate variability over the same period, we have proposed the following scenarios for our analysis:

Modeling assumptions

		Scenarios		
Variable	Unit	Low profit	Base case	High profit
Network hashrate	TH/s	150,000,000	110,000,000	70,000,000
Bitcoin price	$	4,000	8,000	12,000
Electricity charge	$/kWh	0.04	0.03	0.02
Pool fee	%	4%	3%	2%

(Source: Elwood research)

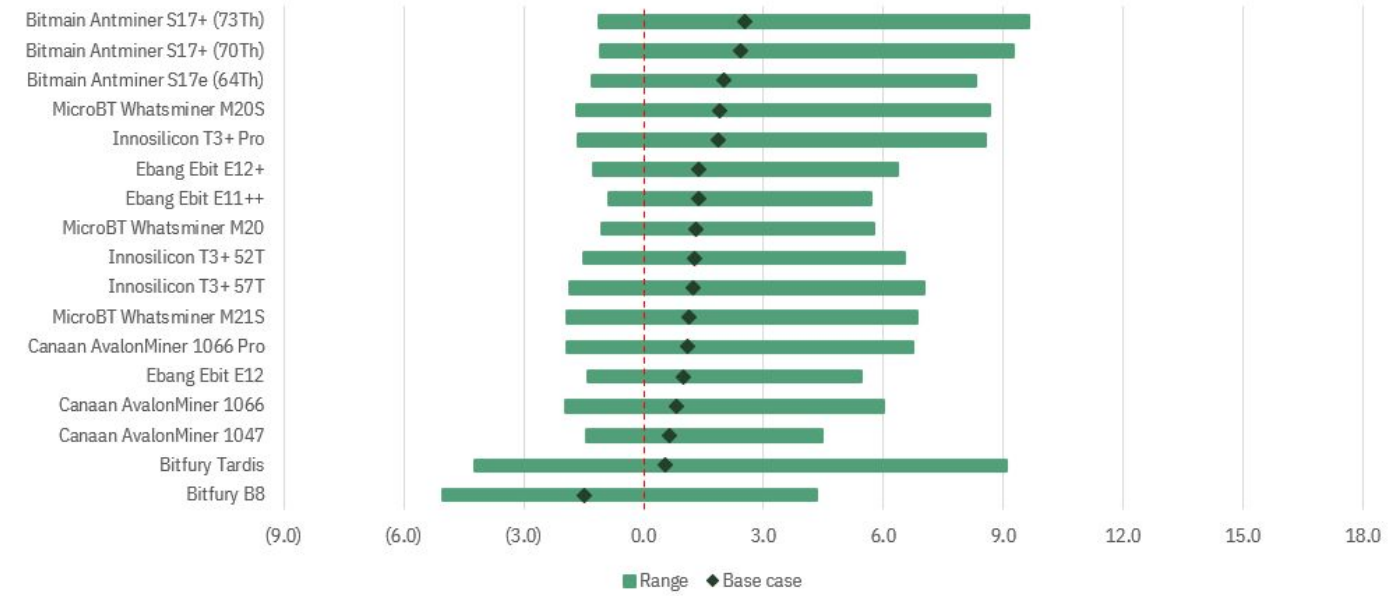
- **Base case scenario**: assumes a network hashrate at a similar level as of the time of writing, Bitcoin price slightly below the last 12 month average, electricity charges in line with reported by company management teams and pool fees at the mid range between the highest and lowest fees observed in the market.
- **Low profit scenario**: assumes the network hashrate to continue increasing, reaching 150 EH/s, as well as a Bitcoin price slightly lower than the minimum observed over the last 12 months. In this scenario, we add 1 cent to electricity charges and assume pool fees at the higher end of the observed range among the largest operators.
- **High profit scenario**: assumes a network hashrate of 70 EH/s, slightly lower than the last six month minimum and a Bitcoin price slightly below the highest observed value over the last twelve months. In the high profit

scenario we reduce electricity charges to US$0.02/kWh and set pool fees to the lowest observed values among top operators.

Profitability analysis

Using the scenarios above, we have run our model using the specifications of 73 different ASIC miners from the manufacturers mentioned in the beginning of this section. Below we have charted the profitability ranges of the top 3 performing miners from each manufacturer:

Current generation cryptocurrency miner daily profitability ($/day)

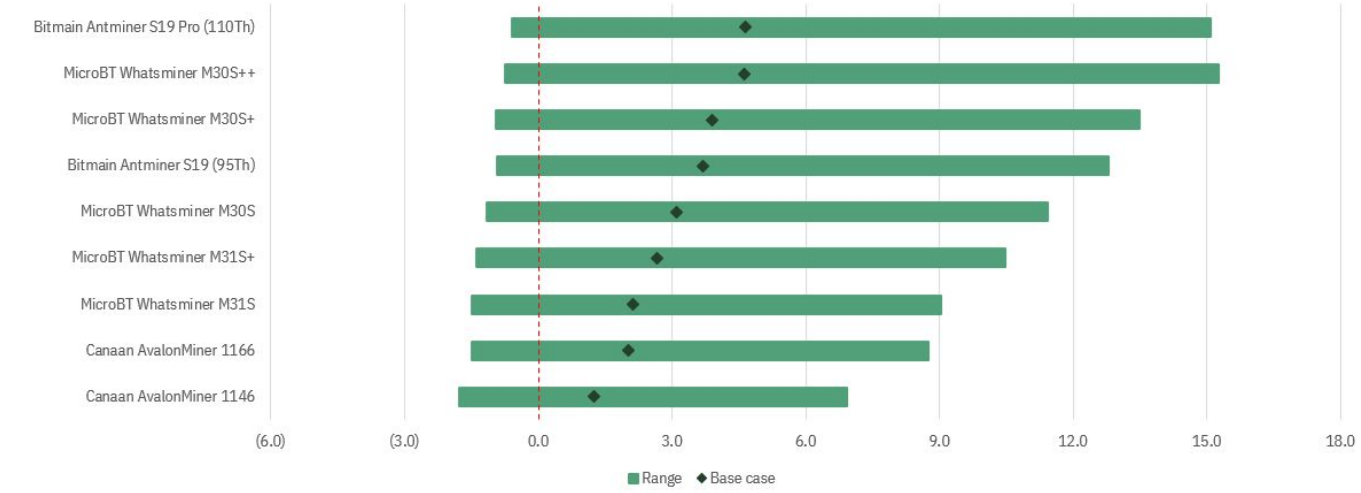


(Source: Elwood research)

Our analysis shows that, among current generation miners, Bitmain has the lead, and the top three most profitable miners are made by the company, followed by MicroBT's Whatsminer M20S and Innosilicon T3+ Pro. Unsurprisingly, all top 5 models have been released in the second half of 2019 and account with the latest technology in ASIC manufacturing. Bitfury has the worst performing models, with the B8 being the only of the top 3 models by our selected manufacturers to have negative profitability in our base case. However, Bitfury does have the oldest miners in our analysis and are not as well equipped with highly efficient technology as its competitors.

We have also analysed new generation models by the abovementioned suppliers (announced since December 2019), specifically Bitmain's Antminer S19 series, Canaan's AvalonMiner 11 series and MicroBT's Whatsminer M30S and M31S series.

New generation cryptocurrency miner daily profitability ($/day)



(Source: Elwood research)

Again, Bitmain takes the top spot in the profitability ranks with the new Antminer S19 Pro, followed by MicroBT's Whatsminer M30S++ and M30S models. The Antminer S19 Pro will have the best efficiency of any ASIC miner ever released, at 30W/TH, closely followed by the Whatsminer M30S++, with 31W/TH. Canaan, the only listed ASIC manufacturer, has the least profitable machines among the new models, although still showing an improvement against the AvalonMiner 10 series.

However, just like the current generation models, the new miners are all vulnerable to cryptocurrency price slumps and increased competition on the network, and reach negative profitability in our low scenario.

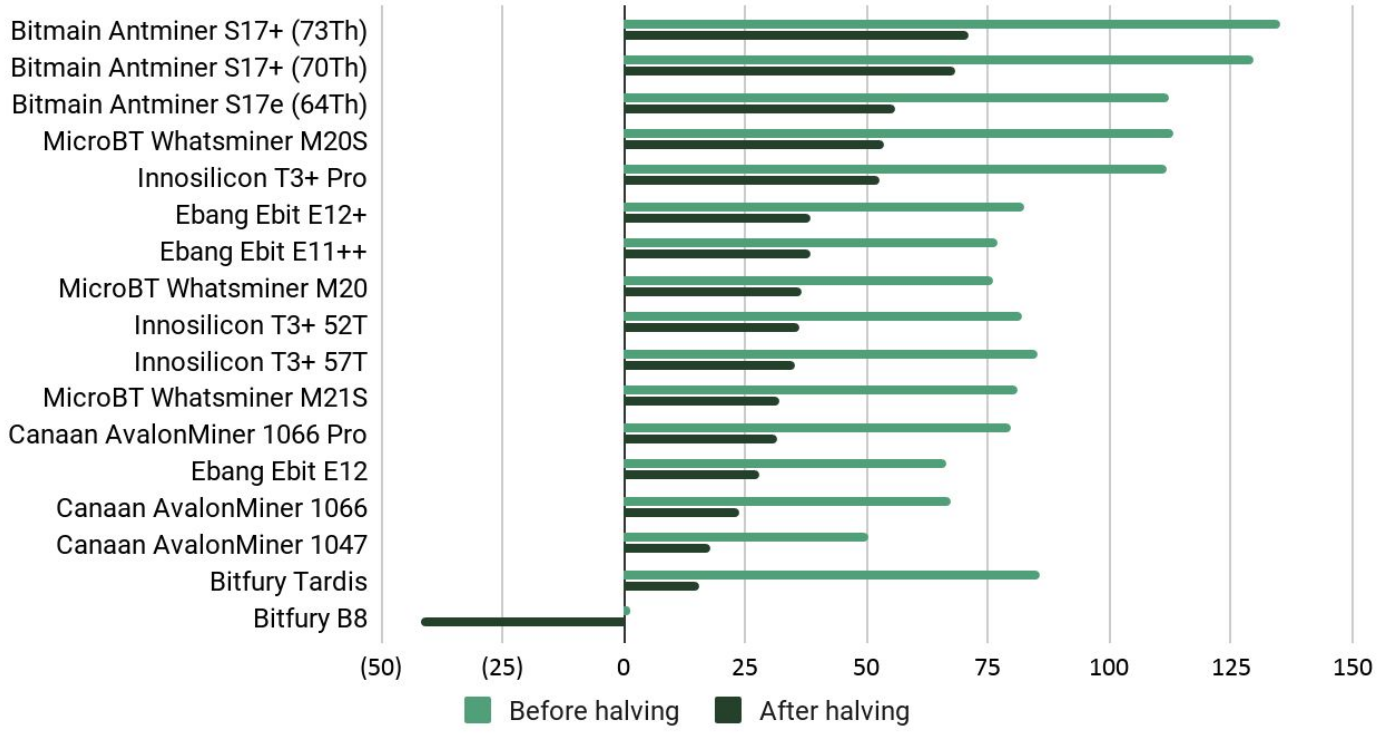
The Bitcoin halving effect

On 11 May 2020, the Bitcoin block subsidy reduced from 12.5 per block to 6.25 per block. As one would expect, this had a considerable impact on the network, effectively reducing miner revenues by half overnight and a meaningful reduction in profitability as well. However, as mentioned above, there are other factors that affect miners' profitability, such as network hashrate and difficulty. With lower rewards and revenue, it is expected that a significant number of mining equipment will go out of business at the current bitcoin trading range, which, in turn, would reduce network hashrates and difficulty, consequently increasing miner profitability again until an equilibrium is reached.

Although, at the time of writing, the halving event was a recent one, we have attempted to measure the impact that this has had on mining profitability. In order to perform this analysis, we used the 3% pool fee and US$0.04/kWh electricity cost assumptions from our base case scenario, and combined them with the prevailing daily network hashrate and bitcoin prices, as well as each individual miner hashrates and efficiencies. We have then calculated and added up the daily profits from the three-week periods before and after the halving and compared them against each other.

Most of the top 3 machines from each manufacturer remained profitable throughout the two periods, except for the Bitfury miners, whose B8 model did not make a profit in any days after the halving. The average profit loss was of 58% across these miners, with Bitfury and Canaan miners losing most of their surpluses on a relative basis, but with also MicroBT's Whatsminer M21S and the Ebang Ebit E12 faring below average.

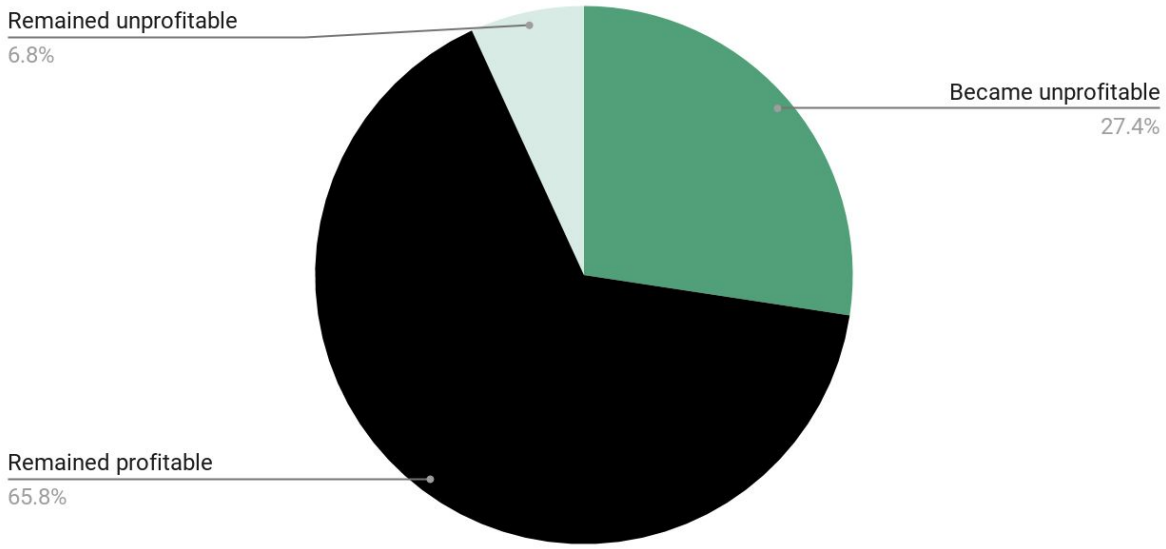
Total three-week profit before and after the Bitcoin halving event ($)



(Source: Elwood research)

We also analysed the broader sample of the 73 miners (including the ones above) of the selected manufacturers released after 2017. Among these, 20 models, or 27% of them, became unprofitable when comparing between the two three-week periods, while 66% remained profitable and 7% were unprofitable during both periods.

Change in profitability among cryptocurrency miners



(Source: Elwood research)

Among the models that turned unprofitable are most of the very popular Bitmain's Antminer S9 series models, as well as Canaan's Avalonminer 8 series, Ebang's E9 and some E10 series models and Innosilicon's T2 Terminator. The fact that the Antminer S9 has become unprofitable is not surprising as they are some of the oldest Bitmain models in our

sample. However, this suggests that a significant proportion of the total network hashrate is likely to come offline. We believe this can explain part of the 30 EH/s network hashrate reduction in the days following the halving event.

This analysis has been done with a restricted time frame and conditions are likely to be fluid over the next few weeks and months, with otherwise marginally profitable machines turning unprofitable and vice-versa, until newer and more powerful machines take a higher share of the network hashing capacity. Either way, we are confident that the Bitcoin halving will take a number of models out of the market and operators who wish to continue mining Bitcoin will have to upgrade their machines. Initially, this is likely to shake-up the second-hand market, but eventually the upgrade chain will flow through to manufacturers, which could provide a windfall in revenues to these players into the second half of the year.

Break-even analysis

Another angle through which this analysis can be done is by assessing the break-even price at which they become profitable, under certain conditions. In order to perform this analysis, we have reworked our daily profitability model into a break-even price model:

$$P = \frac{N \times e \times E}{37500} \times \frac{1}{1-f}$$

Where:

P = (Bitcoin) price
N = Network hashrate
e = Efficiency rate
E = Electricity charge
f = Pool fee

For this analysis, we continue using our low profit, base case and high profit scenarios, but since the goal is identifying the break-even price, we have removed this variable from the scenarios, leaving only three assumptions.

Break-even modeling assumptions

		Scenarios		
Variable	**Unit**	**Low profit**	**Base case**	**High profit**
Network hashrate	TH/s	150,000,000	110,000,000	70,000,000
Electricity charge	$/kWh	0.04	0.03	0.02
Pool fee	%	4%	3%	2%

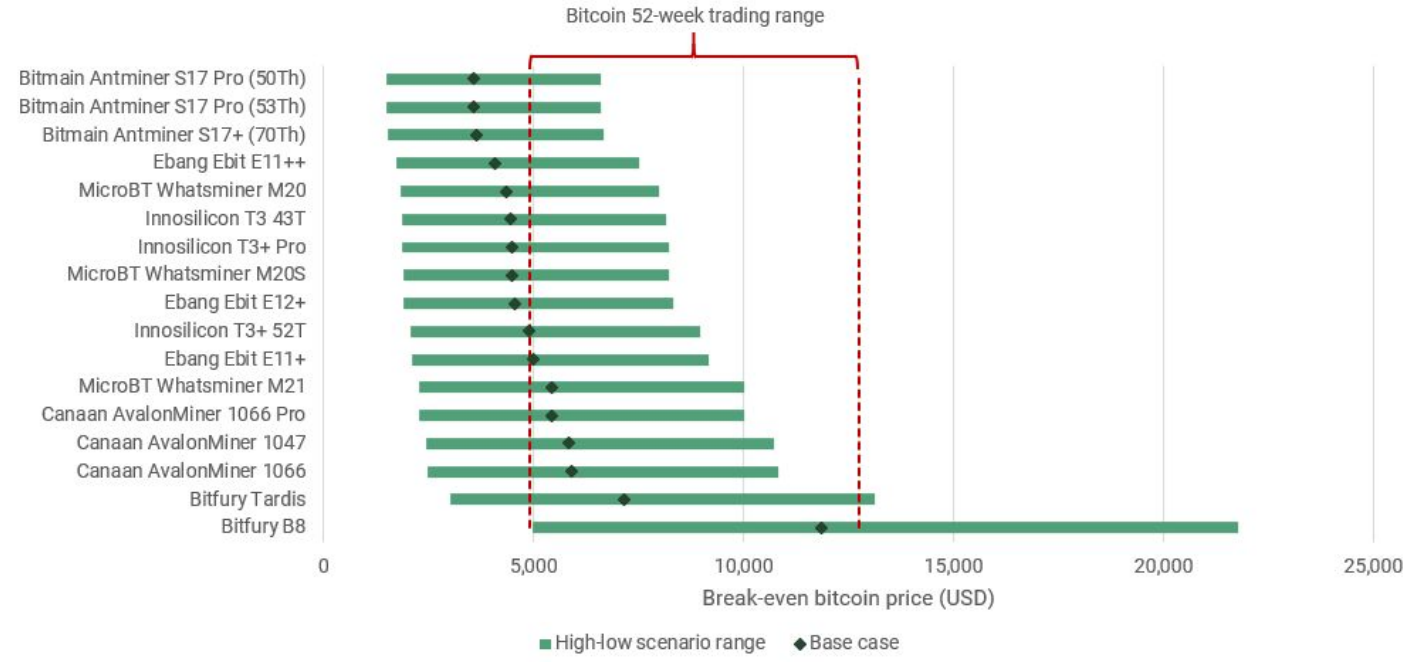
(Source: Elwood research)

As this analysis does not depend on miner hashrates, efficiency becomes the pivotal metric and models with high efficiency (i.e. low W/TH measurements) will achieve the best (i.e. lowest) break-even prices.

Using the same sample as in the section below, we have picked the top three performing models from each manufacturer and Bitmain's S17 models came out on top again, with the S17 Pro models breaking even at $3,584 and the S17+ at $3,629. However, Ebang jumped up and took the next spot from MicroBT's Whatsminer M20, which came in fifth place.

In addition, we have added Bitcoin's 52-week high and low prices to the chart. The top performing machines have their break-even points comfortably below the 52-week lows, while, under our base case, Bitfury's B8 breaks even at almost the highest observed bitcoin price over the last year.

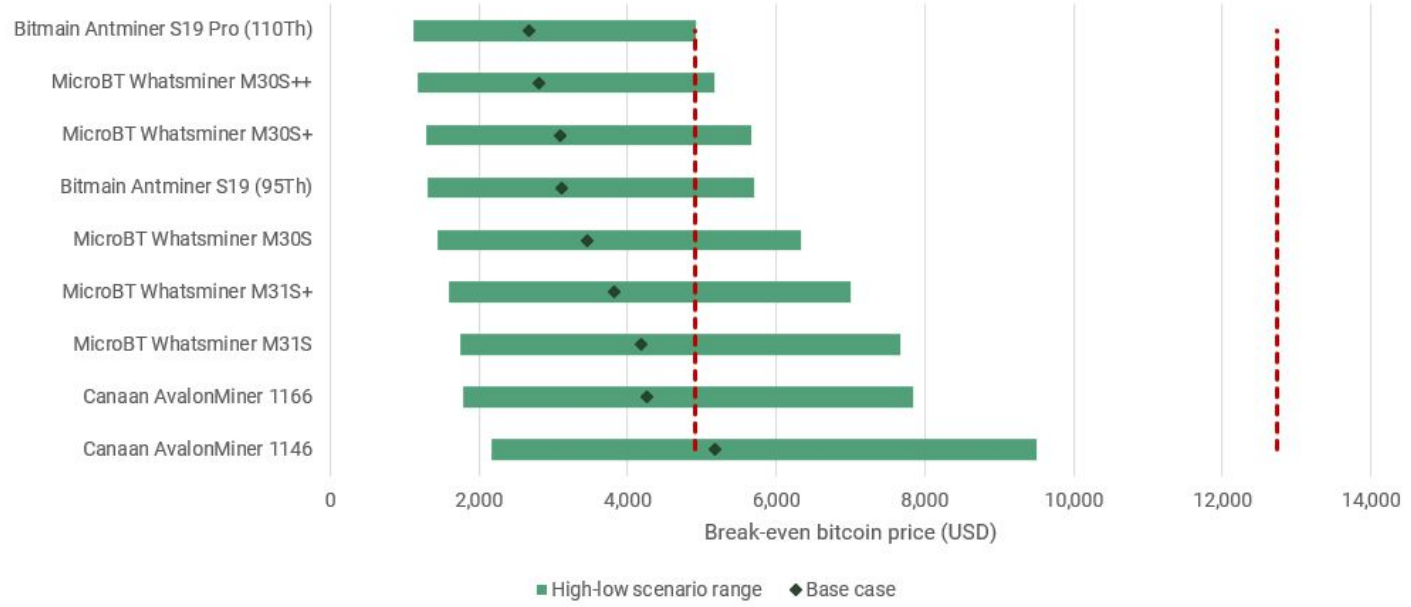
Break-even bitcoin price by miner



(Source: Elwood research)

Below, we also show the new generation models. The top-down order is exactly the same as in the profitability charts, and with most models' break-even points, except Canaan's AvalonMiner 1146, falling below the 52-week low observed bitcoin prices, and not reaching anywhere near the highs, even at our low profitability scenario.

Break-even bitcoin price for new generation miners



(Source: Elwood research)

This analysis makes it clear that new generation models are far more resilient to volatility in bitcoin prices and are far more likely to be in the money than older generation equipment, increasing the appeal of new machines to bitcoin mining operators. However, there is one caveat - is the capex worth the additional efficiency?

Net present value analysis

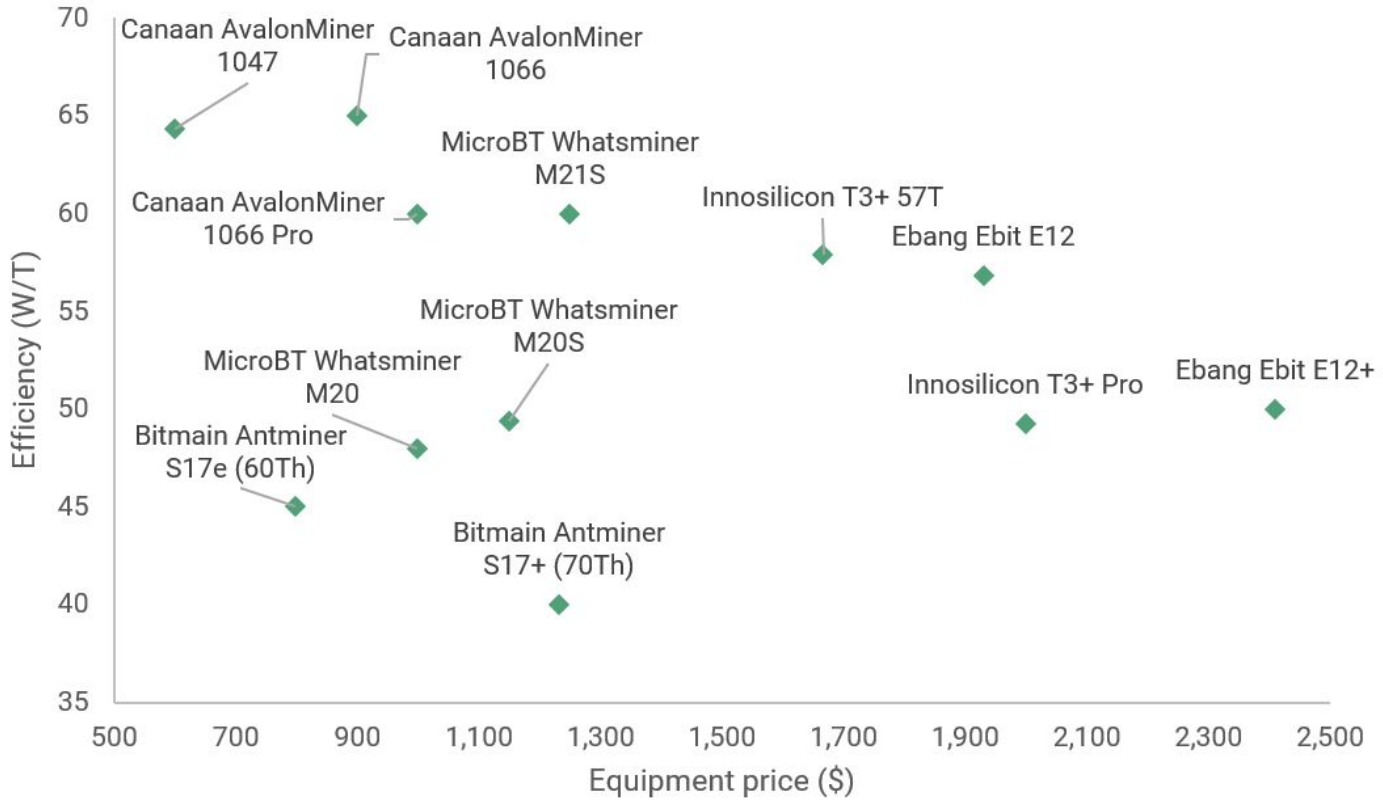
While there are differences in efficiency and hashrate between different pieces of equipment, there are also differences in price, which may have an impact on internal rates of return and the overall attractiveness of machines as an investment decision. In this section we attempt to provide a net present valuation of each of the top 3 cryptocurrency miners by manufacturer.

Although a number of assumptions need to be made, it can help validate the results of the previous section. In this analysis, our sample has been reduced from 17 to 12 models, as there is no current reliable pricing information for all machines at the time of writing.

As an initial analysis, we have plotted the models on a scatter chart to assess whether money buys more efficiency or not. In the chart below, the better performing models should be approaching the bottom left corner (lowest W/TH and lowest $ price), while the worst value for money lies at the top right end of the chart.

In terms of dollar per efficiency, Bitmain and MicroBT have the best models, with Ebang and Innosilicon being the worst. Among the Canaan models, the AvalonMiner 1066 Pro is clearly a better choice against the other two models in the analysis.

Equipment price vs. efficiency rates



(Source: Elwood research, company data)

In order to calculate each individual miner's net present value (NPV), we needed to make assumptions around the cost of capital. In order to reflect the inherent risks of using mining equipment, we used a blend between listed mining equipment operators (Hive Blockchain, Hut 8, Argo Blockchain and Bitfarms) and manufacturers (Canaan) in order to reach an approximate WACC.

WACC assumptions

Factor	Value
Risk-free rate	1%
Equity market premium	10%
Beta	1.3
Unlevered cost of capital	**14%**

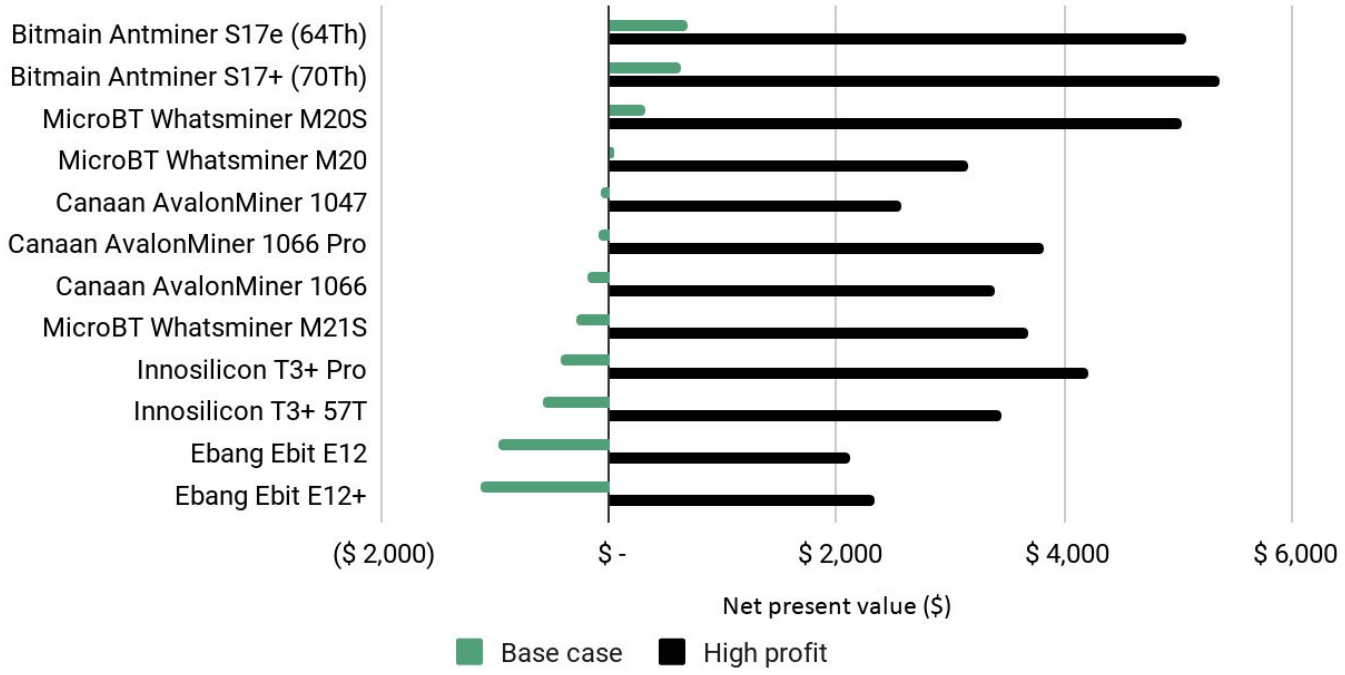
(Source: Elwood research)

In addition to cost of capital, we also made the following assumptions:

- Equipment purchase happens in day one of year one
- Equipment operating life of 3 years with no salvage value
- Cash flows are converted into fiat (USD) at year end (i.e. revenue realisation)
- Machines operate 24 hours a day, 7 hours per week and 365 days per annum
- Post-depreciation tax rate of 18%

We have run our model based on the initial assumptions presented at the profitability and break-even analysis sections. We have excluded the low profitability scenario from the analysis below as all miners were unprofitable under those conditions and would have yielded negative results.

Cryptocurrency miner NPV analysis



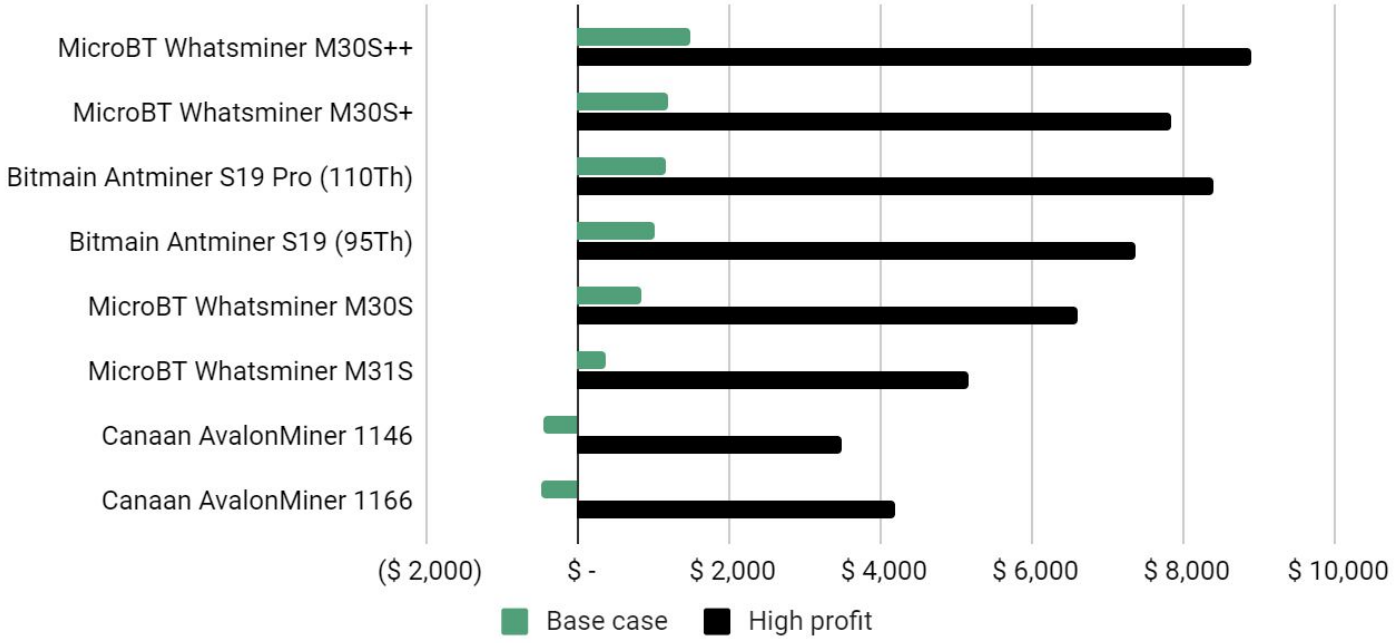
(Source: Elwood research)

In our base case, only four miners are NPV positive: Bitmain's Antminer S17e and S17+ and MicroBT's Whatsminer M20S and M20, followed by Canaan's models nearly breaking even. These results are in stark contrast with our initial profitability analysis, which had all models in the chart above as profitable under our base case conditions, suggesting that price plays a significant role in equipment choice.

In the high profit scenario, Bitmain's models take again the lead, followed by MicroBT Whatsminer M20S and Innosilicon T3+ Pro, suggesting that, despite having a higher price tag, ($1,999 at the time of writing), Innosilicon's model can be a good choice if mining conditions are expected to be beneficial going forward.

Switching to new generation cryptocurrency miners, for the first time a Bitmain model is not at the top. MicroBT's Whatsminer M30S++ achieves the highest net present value in both base case and high profit scenarios, followed by the M30S+ in second place in our base case, but with Bitmain's Antminer S19 Pro taking the second spot on the high profit scenario. Only two models come out with negative NPVs in this analysis, and they are both Canaan's AvalonMiner series 11 machines.

New generation cryptocurrency miner NPV analysis



(Source: Elwood research)

Equipment review conclusion: winners and losers

In a very volatile market, where prices can change by nearly $5,000 in a single week, it is essential to invest in efficient and profitable equipment. Our analysis has shown that there are considerable differences between models in terms of price and performance, which have a direct impact on business profitability. Within budget restrictions, mining operators are likely to choose the highest NPV machines and, in this respect, two brands clearly stand out: Bitmain and MicroBT. These two manufacturers also offer the most profitable equipment, providing an additional buffer against the inherent cryptocurrency market volatility, further protecting operators' earnings. Among the listed players, Canaan, does not come out on top, but it has become clear that the company tries to appeal to a lower budget end of the market and could see some operators adopting its machines, although they will be likely to be the most price sensitive end of the market.

Index companies

Although most manufacturers on this report are not listed companies, some of their suppliers are. Large semiconductor manufacturers such as Samsung and TSMC are considerable players in this space, providing ICs to most of the models analysed and this report and, therefore, have part of their sales are directly correlated to cryptocurrency machine sales. In the following section, we examine index companies within the cryptocurrency miner supply chain in the three main stages: design (Global Unichip), chip supply (TSMC, Samsung) and end product (Canaan).

Taiwan Semiconductor Manufacturing (TSMC)

Taiwan Semiconductor Manufacturing (TSMC) is one of the largest semiconductor manufacturing companies in the world. The company provides wafer manufacturing, wafer probing, assembly and testing, mask production, and design services. TSMC's integrated circuits are used in computer, communication, consumer electronics, automotive, and industrial equipment industries.

Since the beginning of ASIC mining, TSMC has had a significant role in providing integrated circuits (IC) to cryptocurrency miner design companies. The largest ASIC design company, Bitmain, stated on its October 2019 prospectus[4] that the company relied entirely on TSMC as its semiconductor foundry partner. The company also supplies Canaan, who states TSMC as its 'major third-party foundry partner' in its 2019 IPO prospectus[5], although Canaan's management has stated that the company is actively seeking to form partnerships with other foundries such as Samsung and SMIC.

Assessing TSMC's cryptocurrency related revenues

TSMC first mentioned cryptocurrencies as a significant source of revenue in its third quarter of 2017, where management stated that it was seeing 'a healthy demand environment, including cryptocurrency mining'[6] and that revenues from cryptocurrencies were between $350 million and $400 million during that quarter, or just under 5% of total group sales in the period.

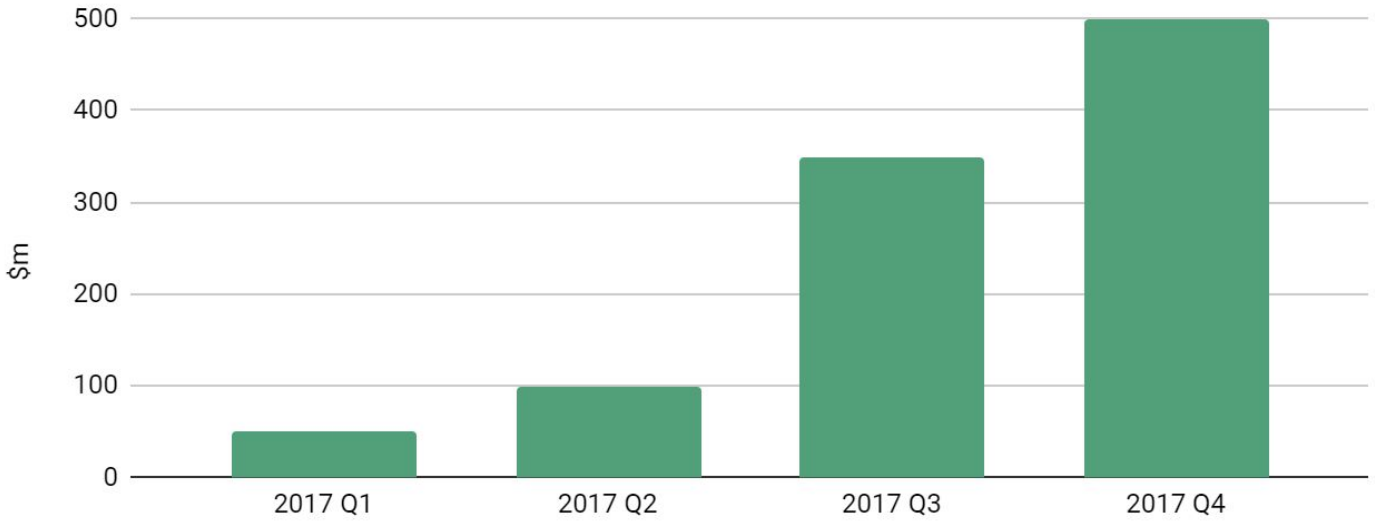
Unfortunately, the company has not disclosed any further data on cryptocurrency related sales since Q3 2017. However, it is possible to infer an approximate revenue level from management comments at analyst calls over the last two years. In order to assess 2017 revenues, we have used the comment in the paragraph above with the quote below:

- In January 2018, with regards to cryptocurrency mining, management said that they 'saw a strong increase in the second half of last year' (Q4 2017 transcript)

This suggests that the bulk of the cryptocurrency related revenue came in the second half of 2017. We have built an estimate cryptocurrency revenue profile for TSMC throughout 2017, starting with low revenues for the first two quarters ($50m and $100m, respectively), ramping up to $350m in Q3 and $500m in Q4, totalising $1bn in revenues for the year, or around 3.1% of annual group revenues:

[4] Source: Bitmain prospectus [link]
[5] Source: Canaan prospectus [link]
[6] Source: TSMC Q3 2017 earnings call transcript [link]

Estimated cryptocurrency revenue profile for TSMC in 2017



(Source: Elwood research, company data)

Further comments have been made in subsequent quarters about the progression of cryptocurrency related revenues at TSMC, from which we attempt to derive the company's 2018 cryptocurrency related sales:

- At the Q1 2018 call, management saw higher demand for cryptocurrency in H2 2018 in relation to H1, with miners switching to more advanced technologies. Also, management stated that revenue from cryptocurrencies was increasing in Q1 2018. (Q1 2018 transcript)
- During the Q2 2018 earnings call, management attributed the strong business performance to high-performance computing (HPC), the division within which cryptocurrency related sales are accounted for. However, the company saw declining demand into Q3 2018 as cryptocurrency prices were weakening. (Q2 2018 transcript)

In addition, further assumptions need to be made around revenues by platform, as they have been reported only since 2018, with no available 2017 breakdown. At the Q4 2018 earnings call Q&A section, management suggested the following:

- '**Smartphone** grew slightly, **IoT** grew double-digit. **Automotive** largely flat. **HPC**, if we're excluding cryptocurrency mining, HPC also grew slightly.' (Q4 2018 transcript)

Using the growth rates above, we have backworked TSMC's revenues by platform, as per the table below:

Revenues by platform (NT$m)	2017E	2018A	Growth	Management commentary
Smartphone	444,284	466,498	5.0%	Slight growth
HPC	313,051	342,644	9.5%	-
IoT	53,518	64,221	20.0%	Double-digit growth
Automotive	51,009	51,009	0.0%	Largely flat
DCE	61,501	58,426	(5.0%)	-
Others	54,084	48,676	(10.0%)	-
Total	**977,447**	**1,031,474**	**5.5%**	**-**

Note: only the breakdown between the different platforms is estimated for 2017, the total corresponds to the actual reported figures.

From our analysis, we can estimate a HPC growth rate of about 9.5% in 2018 and that total platform revenues were somewhere around NT$ 313bn, or $10.3bn in 2017. Combining this analysis with management's statement that 'excluding cryptocurrency mining, HPC grew slightly', we were able to approximate a revenue figure for cryptocurrency sales in 2018. For 2019, management has stated that, excluding cryptocurrency from both years, HPC growth would have been mid-single digits during the year. Assuming mid-single digit corresponds to around 5% on a constant currency basis, we derived the figures below for both years:

	2017	2018	2019
Revenue ($m)			
Cryptocurrency	1,000	1,600	233
Other HPC	9,271	9,760	10,052
Total HPC	**10,271**	**11,360**	**10,286**
Growth			
Cryptocurrency	-	60.0%	(85.4%)
Other HPC	-	5.3%	3.0%
Total HPC	-	**10.6%**	**(9.5%)**
Constant currency growth			
Cryptocurrency	-	58.3%	(85.1%)
Other HPC	-	4.2%	5.5%
Total HPC	-	**9.4%**	**(7.3%)**

As a result, we estimate TSMC's cryptocurrency related revenues in 2018 to have been somewhere around $1.6bn, or NT$ 48.3bn, making up for around 4.7% of company revenues during fiscal 2018. We believe this estimate to be plausible, as the company started the year with strong cryptocurrency sales, higher than Q4 2018, and saw the peak somewhere between Q1 and Q2, observing a subsequent decline into the second half of the year. For 2019, we have a considerable drop, to around $250m, which is in line with management's expectations of a big drop in cryptocurrency contribution for 2019 earlier in the year.

Understanding TSMC's underperformance in 2019

TSMC management attributes price appreciation and the overall media hype to the 2017 and 2018 high levels of cryptocurrency related sales. However, slightly deeper analysis suggests that 2019 sales, although lower than 2018, seem to be abnormally low, especially given TSMC's relationship with the industry's leading player Bitmain. The bitcoin network hashrate has steadily increased since 2016, suggesting that there has been continuous investment in new mining equipment.

We have extracted the peak network hashrates for each year since 2016 and compared the changes between each year in order to identify the annual net increase in total network hashrate. We then compared the annual deltas with the average miner size (measured in terahashes) in order to achieve an indication of how many new machines could have been installed between each peak.

Year	Peak hashrate (Th/s)	Net increase in hashrate (Th/s)	Average miner size (Th/s)	Net new miners
2017	15,363,575	12,773,625	15.9	802,812
2018	60,089,527	44,725,952	25.2	1,772,378
2019	109,144,376	49,054,849	48.5	1,012,233

The data above suggests that there was indeed a large drop in miner sales between 2018 and 2019. However, not to the scale that our derived data for TSMC suggests. There are a number of factors that could have contributed to this mismatch, such as:

- **Project lead time**: Some of the sales discrepancies can be attributed to the lifecycle of new hardware projects. By the time a new model hits the market, R&D spend, manufacturing and stock preparation for releases would already have been done in advance, which would lead to a higher mismatch between final product sales and suppliers higher in the supply chain.
- **Inventory build-ups and drawdowns**: Related to the above, is the mining hardware companies' strategies with regards to building up and drawing down into their inventories. If a company decides to significantly build up inventory, that would mean that, for companies such as TSMC, a very high amount of sales would be booked before final sales happen, contributing to a mismatch between chip sales and changes in network hashrates.
- **Pricing**: New machines have larger and more efficient chips. However, this does not mean that TSMC is able to cash in all efficiency gains, and chip prices are not likely to have gone up with increases in efficiency or machine power. A typical example of this in consumer retail is Apple charging the same price for a new iPhone generation, despite older phones having less features or less powerful processors.
- **Competition and market share**: Another factor that could explain TSMC's lower than expected cryptocurrency related sales is loss of market share against competitors. Although having a solid relationship with Bitmain, there are other highly efficient machines that do not use TSMC ICs which could be gaining market share. Additionally, there are cryptocurrency mining hardware companies that are aiming to reduce their dependence on TSMC, diversifying their projects to other companies, reducing TSMC's overall share within those clients.

Whether or not there will be a similar wave of interest for cryptocurrency as there was in 2017 only time will tell. However, this time TSMC and its clients are likely to be faced with far more competition, which could prove a headwind to sales growth in this area. However, the company is well positioned as the world's largest foundry, supplying the largest and, to date, best cryptocurrency hardware manufacturer, and, as a result, cryptocurrencies remain a key area for TSMC despite the inherent sales and price volatility.

What cryptocurrency revenues represent to TSMC's valuation

TSMC's cryptocurrency business was effectively created from scratch in 2016 and has generated 5% of company sales in at least one quarter or more. In previous talks with TSMC, the company stated that the cryptocurrency business has the same high EBITDA margin as the rest of the group, at around 65%.

Although the Bitcoin halving has created increased hurdles to industry profitability, our previous analysis has shown that new cryptocurrency miners can still be profitable even at subdued prices, and with TSMC being the main chip supplier of the industry's largest player, the company could see considerable benefits from being at a dominant position in this market.

However, in 2020, we do not see TSMC achieving as high levels of sales as it did in 2017 and 2018, but our 2019 estimate does not set a very high bar and we believe the $250m could be easily beaten, perhaps achieving somewhere

around $500m for the year. If value the cryptocurrency related revenues at a 20% premium to the business, which trades at 6.5x sales, it would be worth $3.9bn, or just under 1.4% of the business' current value.

Canaan

Until Ebang's recent IPO in June 2020, Canaan was the only listed company among the major cryptocurrency equipment manufacturers. In addition to both companies, Bitmain filed for an IPO in 2017, but did not go ahead with the listing process.

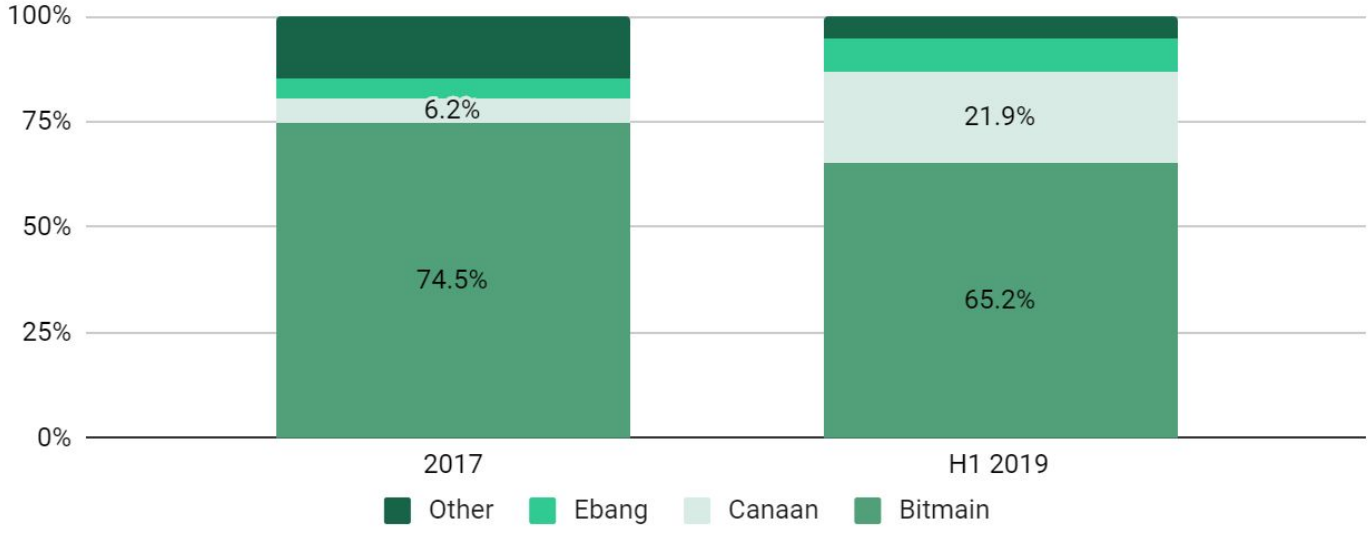
The company was founded in 2013 and is based in Hangzhou, China. Canaan was the first company to develop ASIC-based miners, with its first machine, the Avalon1 series, being introduced in 2013, with a mining power of 72 GH/s. Below we show a table with commonplace mining hardware from the time, and the impact that these new machines had in the industry becomes clear:

Chip	Manufacturer	Model	GH/s	Power (W)	Efficiency (W/TH)
GPU	ATI	Radeon HD 5830	0.25	153	612,000
GPU	ATI	Radeon HD 6990	0.70	357	510,000
FPGA	Butterfly Labs	BFL Single	0.83	80	96,386
FPGA	Butterfly Labs	BFL miniRig	25.2	1,200	47,619
ASIC	Canaan	Avalon1 3module	72.0	600	8,333

(Source: Elwood research, Tom's Hardware)

Until the second half of 2017, Bitmain and Canaan were the main ASIC miner suppliers in the market and were competing neck and neck against each other, but without significant competition from other companies. Market research company Frost & Sullivan estimated the cryptocurrency mining equipment market to be around $3bn in 2017, heavily dominated by Bitmain, with Canaan in second place with just over 6% of market share in that year. The more recent Canaan IPO filing provides more recent data and suggests that Canaan now holds around 23% of the market, when measured by hashrate sold. We suspect Canaan's dollar share could be below that as its miners sell for slightly lower prices.

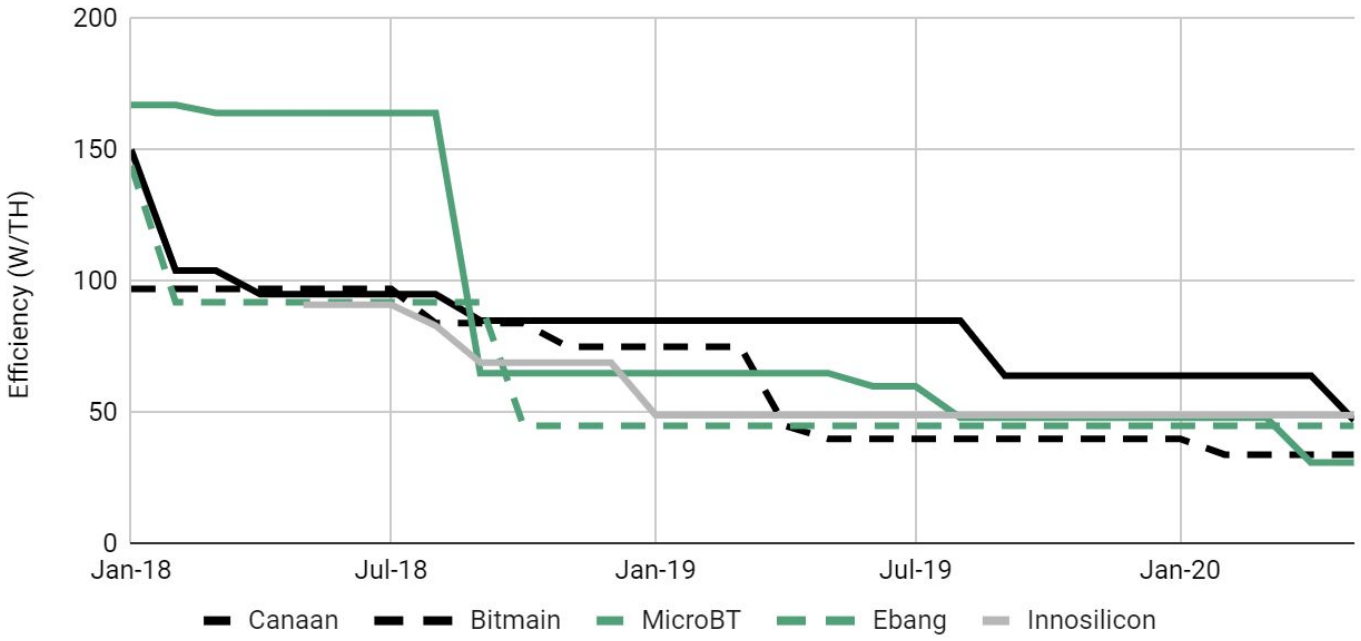
Cryptocurrency miner market share



(Source: Elwood research, Canaan and Bitmain IPO prospectus)

Despite Canaan's relatively high market share in H1 2019, new entrants could represent a significant threat to the company's position in the market, despite its longer track record and reputation. As the chart below shows, technology wise, Canaan's products are not the most advanced in the market anymore, and the recent Bitcoin halving will certainly push its customers to acquire newer and more efficient equipment.

Best performing cryptocurrency mining hardware by manufacturer through time

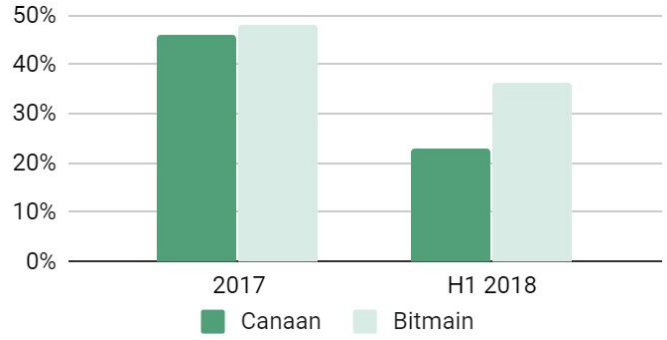


(Source: Elwood research)

Given that technology edge cannot explain Canaan's success in retaining market share, we believe that the company has strived for a price strategy. In order to assess that, we have compared the company's financials against Ebang, but mainly Bitmain.

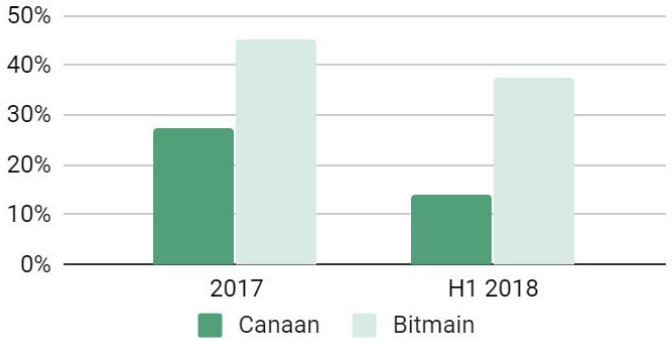
Unfortunately we are only able to compare 2017 and H1 2018 figures between Canaan and Bitmain. Both companies are relatively similar at the gross margin level, with Bitmain faring just slightly higher at 48.2%, against Canaan's 46.2% in 2017. However, Bitmain's sheer scale and market dominance means that the drop-through effect of higher absolute sales translates into much higher operating margins, at 45.4% against Canaan's 27.4%. Going into H1 2018, both companies see some gross margin deterioration, but Bitmain has managed to preserve a higher proportion of it, recording 36.2% gross margins in the period, against Canaan's 23%. On an operating level, Bitmain has *higher* margins, at 37.6%, and that is due to the company's own mining operations (gain on sale of cryptocurrencies) and VAT refunds.

Canaan vs. Bitmain - Gross Margins



(Source: Elwood research, company data)

Canaan vs. Bitmain - Operating Margins

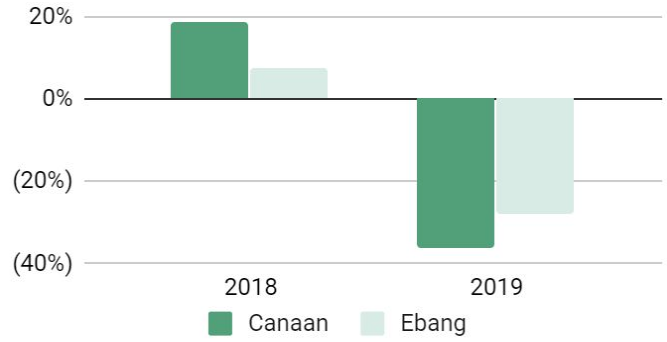


(Source: Elwood research, company data)

Although Bitmain financial data is not available for periods after H1 2018, media reports suggest that the company booked in Q3 2018 just a fraction of revenues in relation to the previous quarters and a net loss of nearly $500m, equating to almost half of the profits booked in H1 2018 ($953m). This shows that a deceleration in hardware sales after the slump in cryptocurrencies, plus its higher exposure to cryptocurrencies themselves leaves Bitmain a very volatile play if it ever becomes listed as a public company.

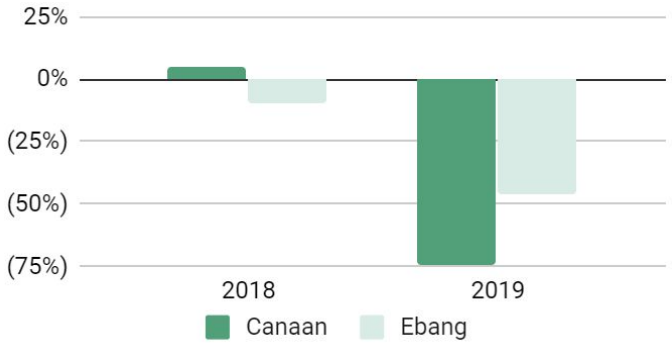
We were able to also compare Canaan against Ebang, a smaller and lesser known player in this market. Against Ebang, Canaan has had better margins in 2018, but higher losses by Canaan in 2019 show that a larger corporate structure could leave companies more vulnerable to downturns in their underlying markets.

Canaan vs. Ebang - Gross Margins



(Source: Elwood research, company data)

Canaan vs. Ebang - Operating Margins



(Source: Elwood research, company data)

Although we haven't had access to market data for the whole of 2019, we believe that Canaan has probably maintained its high market share or even increased it. H2 2019 revenue was nearly 4x as much as in H1 2019, which is understandable, as Bitcoin had a much better performance in H2 2019 than in H1. However, in Q1 2020, Canaan's quarterly results showed that the company only booked $9m in revenues, which is only higher than Q1 2019 ($7m), but in a much better Bitcoin price environment.

Canaan's latest equipment, the AvalonMiner 11 series, does lag behind its competitors, especially the Bitmain Antminer S19 series and the MicroBT Whatsminer M30 series, and we would not be surprised if Canaan's relative low product appeal could be behind the company's poor performance in Q1 2020 and, possibly, Q2 too.

Manufacturer	Model	TH/s	Power (W)	Efficiency (W/TH)
Canaan	AvalonMiner 1166	68	3,196	47.0
Canaan	AvalonMiner 1146	56	3,192	57.0
Bitmain	Antminer S19 Pro	110	3,250	29.5
Bitmain	Antminer S19	95	3,250	34.2
MicroBT	Whatsminer M30S++	112	3,472	31.0
MicroBT	Whatsminer M30S+	100	3,400	34.0

The company has disclosed that there are new models under development, and that possibly 5 nanometre-based machines could be underway for 2021. However, until then, with the company's current series of equipment, it is unlikely to attract enough sales to break even during the year and, as a result, we believe Canaan could have significant market share losses throughout the year.

Global Unichip

Global Unichip (GUC) is a small, fabless, pure IC design company based in Taiwan. The business is 35% owned by TSMC and both companies have maintained a very close relationship, from project exclusivity to TSMC board members being part of GUC's management team. The company operates in two main segments:

- **NRE (Non-recurring engineering)**: This segment is involved in chip design (both front- and back-end design), striving for efficient and small chips, produced at a fast timescale. Margins range between 30% and 50%, within which the front-end designs have a higher margin.
- **Turn Key**: Relates to projects identified by the company as with potential to go into mass production. Orders are placed with TSMC through TSMC. The gross margin in this area is around 10% to 13% and some projects are initially loss-making on an operating level and, as sales ramp, R&D costs are covered and profitability increases.

GUC's customers include fabless companies, which create the front-end design themselves, outsourcing the back-end to GUC in order to achieve higher efficiency in the process. GUC also services what the company says are System Companies, which are customers with their own end products. Applications are varied, but range from drones, digital cameras, game consoles, AI, SSD for servers and PCs and cryptocurrencies.

The role of cryptocurrencies at Global Unichip

Cryptocurrencies were a major revenue contributor to GUC during 2017 and 2018, making up 28% and 24% of company revenues in each year, respectively. In 2017, Global Unichip was involved in 16nm projects with a major undisclosed customer from China (although Bitmain has been ruled out). However, from 2018 onwards, the client switched to working directly with TSMC.

During 2018, GUC was working with a Japanese company on a 7nm process for cryptocurrency applications, but the product was not successful, mainly as a result of the Bitcoin market crash in that year. In our research, we have identified only one Japan-based company with a cryptocurrency miner project, GMO internet. We have managed to gather information about GMO's cryptocurrency mining machines, which are listed below:

Model	Release	Hashrate (TH/s)	Power (W)	Chip size (nm)	Chip name	Efficiency (W/TH)	Algorithm
GMO miner B3	Nov-18	33	3,417	7	GMO72b	103.5	SHA-256
GMO miner B2	Oct-18	24	1,950	7	GMO72b	81.3	SHA-256

As the table above shows, the GMO miner B2 and B3 release dates as well as the chip size (7nm) corroborate with our view that Global Unichip was working with GMO during the 2018 period. However, as mentioned above, the project was unsuccessful, and we believe GUC is not receiving any revenues on device sales anymore. As of May 2020, the GMO miner B2 and B3 were not being sold anymore, but the latest pricing data indicates that they were being retailed for c.$2,000, which would put it at similar levels to top end miners in 2020.

GUC remains a growing business despite declining cryptocurrency related revenues

Excluding cryptocurrency related revenues, GUC's sales grew by 17% in 2018 and, assuming zero revenues from cryptocurrency businesses, revenues were up just under 5% in 2019. The company attributed the overall slowdown in sales to the ongoing trade war between the US and China as well as a recovery from prior an industry inventory correction. For 2020, management expects revenues to grow by double-digit rates, but margins are likely to be down year-on-year due to a higher number of turnkey projects, leading to overall lower project returns.

On the cryptocurrency business side, the company has stated that Bitcoin-related revenues are not considered for this year's guidance and, unless the industry suffers a new sudden rapid increase in interest and investment, we would agree with management's view.

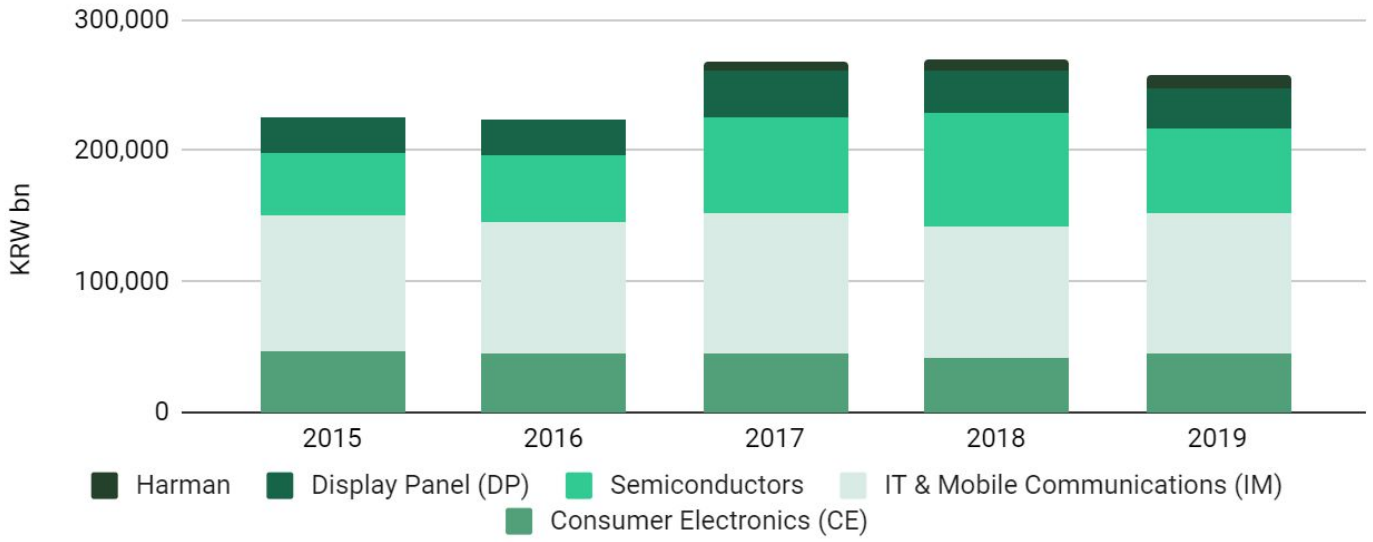
New cryptocurrency projects will depend on reputation recovery going forward

We believe that GMO's venture is not likely to have failed as a result of GUC's efforts on its own. However, the company brand in the cryptocurrency mining industry has certainly suffered some collateral damage from this project. Going forward, we expect ASIC miner specifications to become far more sophisticated than two years ago and, in order to remain competitive in this space, GUC will need to continue investing in R&D and hiring experienced and reputable engineers. The company has stated that its previous experience with Bitcoin projects has resulted in cryptocurrency projects being much quicker and cheaper than before, but, in the competitive cryptocurrency mining industry, price may just not be enough to bring customers on board.

Samsung

Samsung is one of the world's largest consumer and industrial electronics manufacturing companies, with products ranging from telecommunication devices, microchips, personal computers, mobile phones, among others. Although best known for its consumer products, Samsung also acts as a third-party foundry for a number of companies. In 2019, semiconductor sales accounted for KRW 65 trillion, or 25% of company sales in the year.

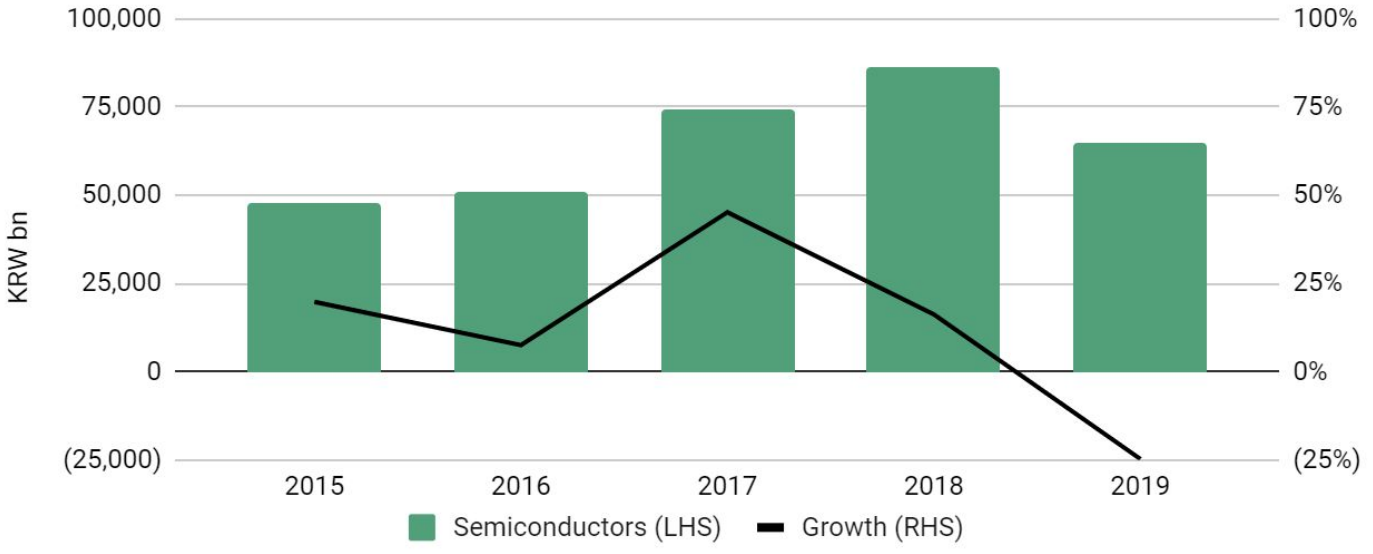
Samsung revenues by segment



(Source: company data)

Although not openly disclosing numbers, Samsung has been indirectly involved in cryptocurrency businesses for a number of years. The company has had a supply agreement with Nvidia, and has produced chips for the company's graphics cards, including GPU-based miners. In 2017, management saw 'explosive' demand for graphics cards due to cryptocurrency mining demand, especially in the 14nm and 10nm processes. As a result, Samsung's Semiconductor business grew by 45% in 2017 and a further 16% in 2018.

Semiconductor revenues and growth



(Source: company data)

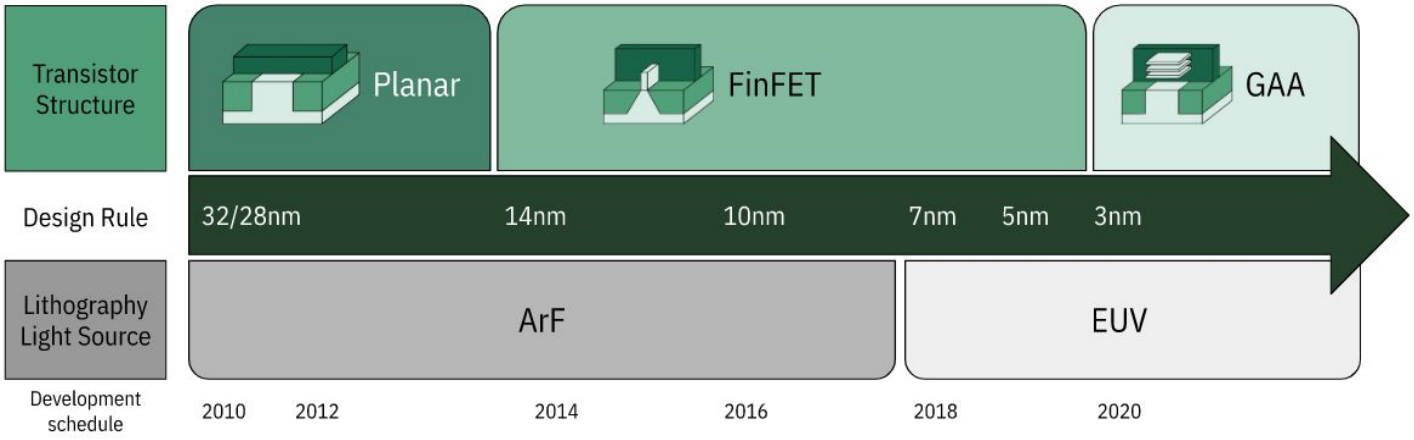
In recent years, Samsung also got involved in a number of ASIC projects. In our understanding, Samsung currently supplies at least three of the major ASIC miner developers: MicroBT, Ebang and Innosilicon. With MicroBT and Ebang already marketing their miners in early 2018, we would assume some of Samsung's 2018 semiconductor revenues can also be attributed to supplying these companies. Innosilicon started shipping its products later in that year and given that it has a lower market share than Ebang, we would assume its contribution would be smaller.

Into 2019, Samsung's management already predicted sluggish demand for mining chips given the poor price performance of cryptocurrencies at the time and, in Q2, the company attributed its lower year-on-year performance to subdued mining chip demand, despite growing demand for other products, such as image sensors and this eventually translated into a decline of 25% in semiconductor revenues in 2019.

Stepping up the competition against TSMC through MicroBT

As our initial section has shown, Bitmain is clearly the player to beat in the cryptocurrency mining hardware industry, and the competition switches to TSMC as we move upwards in the supply chain. Samsung, as the supplier of competitor equipment, would clearly favour being associated with successful machines rather than second-class equipment. The company has been ramping up its semiconductor technology, bringing 8nm chips to market in 2018, 7nm in the beginning of 2020. In Q2 2020 Samsung has started ramping up its 5nm EUV process, which would put the company neck in neck with TSMC for businesses using the latest technology, placing it as a leader in the global semiconductor technology market.

Samsung semiconductor process development timeline



(Source: Samsung)
Note: GAA stands for Gate All Around

In terms of applications within cryptocurrency miners, Samsung is present in MicroBT's Whatsminer machines, which, to date, are the best performing models alongside Bitmain's latest hardware. We believe that the market share figures presented at the Canaan section could easily revert in MicroBT's favour, with Samsung also reaping the benefits on the side. In addition, the recent Bitcoin halving has put further pressure on mining companies to invest in the latest and best technology, which could further boost MicroBT sales, increasing demand for Samsung's chips.

Software solutions

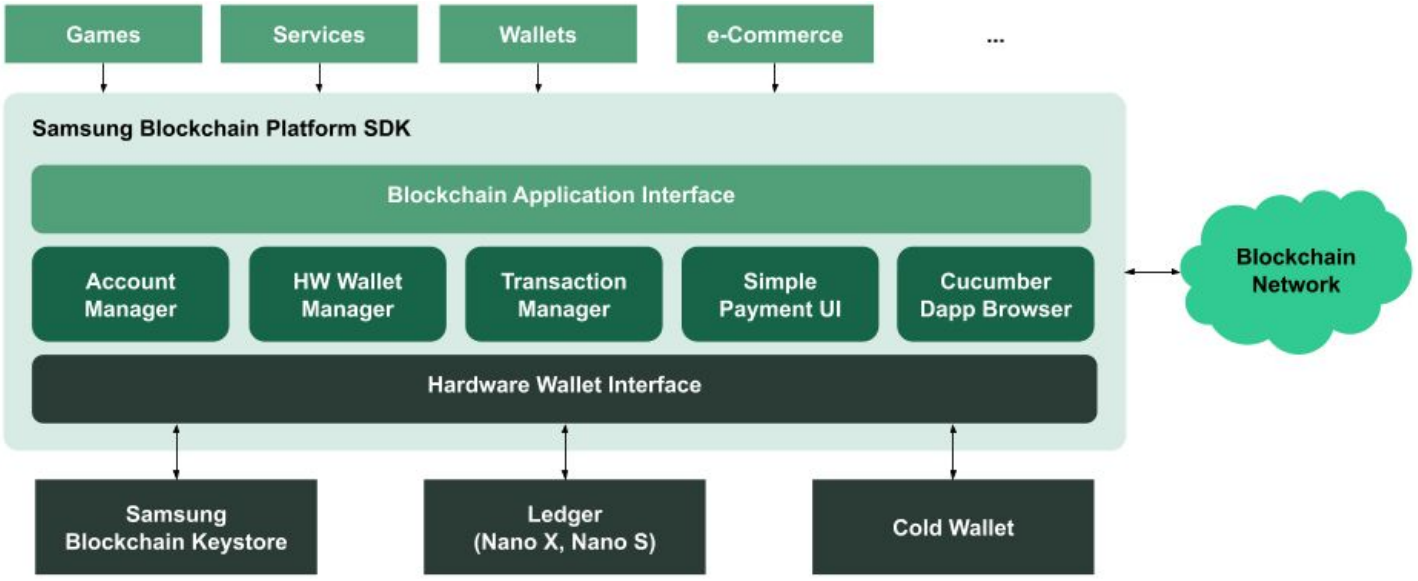
In addition to chip manufacturing capabilities, Samsung has also developed software solutions in the blockchain space. The Samsung Blockchain Platform SDK (software development kit) provides a set of utilities for the ecosystem of decentralized applications (DApps). Industry partners include cryptocurrency payment protocols (e.g., Stellar), blockchain platforms (e.g., Tron) and crypto exchanges (e.g., Gemini).

The abstraction level of the platform helps developers to manage blockchain accounts and make transactions for different ledger systems. The SDK links a DApp to a hardware wallet for secure signing and includes a dedicated blockchain browser solution, *Cucumber*, for the integration of web-based DApps into a mobile environment without any change on the existing web code. The SDK currently supports Ethereum and TRON, and can also be linked with Samsung Blockchain Keystore or Ledger's device.

Features of the SDK include:

- Generation, storage and management of Blockchain accounts.
- Restoration of valid accounts (BIP-44 and BIP-32 standards).
- Creation of transactions via abstracted APIs.
- Retrieval of data from smart contracts.
- Ethereum: ETH, ERC20, ERC721 and raw transaction transfer.
- Tron: TRX, TRC10, TRC20 and raw transaction transfer.
- Various forms of payment UI (e.g., cryptocurrency remittance).
- Hardware wallet integration: Samsung Blockchain Keystore, Ledger's Nano X and Nano S.

Samsung Blockchain Platform SDK Framework



(Source: Samsung Developers website)

Conclusion

Throughout this report we assessed the characteristics and profitability of a number of cryptocurrency mining machines and it has become clear that the most attractive ones are the ones with the best efficiency rates. Today, this essentially translates into equipment made by Bitmain or MicroBT, who we see as market leaders in the short, and perhaps mid-term. As a result, the short-term outlook for Canaan, one of the two only listed companies in the industry, is not very positive, although the company seems to be gearing up for a new generation of miners, which could possibly compete at the top of the market, and revert the negative trend.

We also assessed cryptocurrency mining equipment chip manufacturers, a market currently dominated by TSMC and Samsung. Although companies are very secretive about their clients and information is very scarce, we were able to derive a revenue estimate for TSMC, and concluded that this can be a billion dollar industry, with significant earnings impacts for both companies.

Finally, the new generation of cryptocurrency miners could provide some extra protection against market volatility and slumps and would be welcome additions to mining operators aiming to renew their fleet. If this materialises, cryptocurrency related revenues could again become meaningful to Samsung and TSMC, putting the industry once again at investors' spotlight.

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