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Semester Project

Distribution of ASIC Hardware Models of Public Bitcoin Miners over Time

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Abstract

Bitcoin mining is a growing phenomenon part of the energy industry and has made multiple appearances in public media. Many are staggered that a system like Bitcoin could be demanding electric power comparable to the power demand of nations. This report aims to collect and evaluate bottom-up data published by the Bitcoin mining industry. With these publicly available filings and press releases of the largest Bitcoin mining companies, we analyze the development of deployed ASIC hardware models over the last two years. Our findings indicate multiple steadily and some exponentially growing trends, they shine more light on the hardware manufacturers and show insights into dominant ASIC hardware models. These trends suggest that this emerging industry is growing in significance, and at the same time being in fierce and global competition for the absolute limited resource; Bitcoin. We find a strong duopoly in manufacturers but also promising diversification effects in Bitcoin's total mining fleet. Future research should focus on more bottom-up approaches and data acquisitions to better the understanding of users, policy-makers, critics, and proponents alike on the development and significance of Bitcoin mining.

Keywords: Bitcoin, mining, ASIC, hashrate, public miners, hardware models, proof-of-work

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I learned a lot and could deep dive into the fast-evolving energy field of Bitcoin mining. I got to apply many of my experiences from my studies and internships. Carving connective tunnels in the so-called Bitcoin rabbit hole, expanded my mind, and gave me more clarity and knowledge all built upon countless podcasts, blog posts, books, and videos from passionate content creators, too many to conclusively list. Bitcoin and cyberspace are fabulous place connecting wonderful people motivated for a better future.

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Zurich, August 2024 Samuel Wieland

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Chapter 1

Introduction

Bitcoin has gained over the last decade not only significantly in price but also in its adoption. The decentralized money system with a fixed supply has changed many minds and is now at a point where big corporations and even nation-states are starting to take it seriously. At the heart of Bitcoin is Bitcoin mining. It is the heartbeat propelling Bitcoin through time with every beat, it is a clock that speaks truth to all participants with its every tick. Some research has tried to get a scope of this global phenomenon, but its decentralized structure makes it hard to get reliable and up-to-date metrics on Bitcoin mining. So we took the challenge to gather publicly available documents, meaning public filing and press release documents, of the largest public Bitcoin mining companies and extract insights on this topic.
Our objective is to get more real-world data using a bottom-up approach. We expect to get more clarity into a part of Bitcoin's global computational power, called hashrate, with details not captured by many other studies to this date. We think that the hashrate share of public miners can somewhat be representative of global hashrate, which allows us to do some estimations about global Bitcoin mining. As these estimations rely on multiple assumptions we would think of them more like guesstimates. Either way, it is based on information on various Application Specific Integrated Circuit (ASIC) hardware models, more detailed than found by many top-down approaches. Our approach starts with the acquisition of data. This data will then be completed with a set of rules. With this complete data, we will then be able to do further calculations to get to our results and extract novel insights.

The report starts with two sections on Bitcoin mining and related work. This background information is meant to bring different readers on the same ground of understanding, providing some historical and technical context to know what the process of Bitcoin mining is about and giving an overview of previous research to showcase the state of knowledge regarding some aspects of this industry. Next, we will explain our methodological approach. We will let the reader in on our data acquisition process, we will explain the rules we set to make this data complete and usable and we will state the calculations we did to estimate Bitcoin mining metrics. This chapter is essential to get an understanding of what data and assumptions our results build upon and it will show its strengths and its weaknesses compared to other studies.
The biggest chapter of this report is the results chapter. It is filled with many informative graphs, giving a visual and understandable view of our findings. We structure our results in four steps. Each step removes itself a bit more from the underlying database and takes a few reasonable assumptions into account. These assumptions will be mentioned to have a common understanding. The first step is to look at the aggregated number of ASIC hardware units. This data can be looked at in two ways; looking at the number of units by hardware manufacturer or at the number of units per hardware model. Next, we will compute from these numbers the ASIC hardware hashrate values and again see how the results distinguish by manufacturer and

per model. Then, these hashrates can be shown in percentage terms, showing ASIC hardware shares. Assuming that public Bitcoin mining companies represent a comparable share of the total and global Bitcoin mining, these shares can be looked at as such. Lastly, we will make further assumptions, allowing us to estimate an average Bitcoin mining fleet efficiency. We will compare this result to two other studies. From there we can extrapolate to a guesstimate of Bitcoin's global electricity consumption or power demand. This is a metric covered by multiple studies so far, each taking another approach to get at their estimation. So again we will make a comparison to see where our results land.

In the end, we round up with a discussion of our results before concluding this report and giving an outlook for future research. As the results from our database can be shown in many ways multiple additional graphs, as well as the database itself, are added in the appendix. We made sure to keep consistent wording throughout this report. We write about Bitcoin miners and mean the network entities in the business of block production, such as our analyzed public Bitcoin miners. On the other hand, we write about ASIC hardware units or models, meaning the actual hardware machines or specialized computers doing the actual work of transforming electricity into unalterable proofs for the Bitcoin network, the proof-of-work for the timechain.

Chapter 2

Background

This project dives into some specific and novel information about the subjectively, most important topic of our time: Bitcoin. To guide the reader, this chapter gives the necessary background information on Bitcoin mining. It briefly explains the technological breakthrough of Bitcoin, explains the inner workings and purpose of Bitcoin mining. We will set everything into a historical perspective and finish with an overview of previous work done on the topic of Bitcoin mining.

2.1 Bitcoin Mining

Bitcoin mining is an essential part of Bitcoin's workings, so before explaining the mining part, let us give a few words on Bitcoin. Bitcoin is the decentralized money system. A problem in decentralization is that there is no single source of truth. In the case of a distributed ledger, functioning as money, all participants independently have to find the same truth to prevent double-spending. In distributed computer systems, this problem is known as the Byzantine generals' problem. Satoshi Nakamoto presented in the Bitcoin whitepaper in 2008 a probabilistic solution for this problem using a difficulty-adjusted proof-of-work system. Bitcoin uses a proof-of-work to get a distributed timestamp server [12].

It is implemented using the SHA-256 cryptographic hashing function, which links blocks of transactions together. Each block additionally contains the hash of the previous block and a nonce. The resulting hash value has to land below a certain target value which is set by a difficulty and connects the blocks building a timechain. The nonce, a number only used once, is used to change the value of the resulting hash and acts like a literal guessing game to find a valid hash. A valid block can then be broadcast to the rest of the network. Here is for example the block hash of Bitcoin's 840'000 block:

$$0000000000000000000320283a032748cef8227873ff4872689bf23f1cda83a5 \tag{2.1}$$

The energy used to do these hashing computations bridges the realm of information, the digital, with the physical realm. The timechain decentralizes time, it is a decentralized clock.

Looking at the hash 2.1, the leading zeros result of the target set by the difficulty. A higher difficulty means a lower target hash value needs to be found, hence more zeros show up in this hexadecimal number. With every additional leading zero, it gets exponentially harder to find a valid block. The difficulty adjustment takes the role of the timekeeper. Every 2016 blocks, the difficulty is adjusted to keep the average time per block at 10 minutes. It therefore links Bitcoin's block time to human time, an essential part for Bitcoin to be able to synchronize and to work as money.

Also, Bitcoin's monetary issuance is linked to time in that way. The incentive for so-called miners, doing the work of block production in this guessing game, is the block reward. For every found block the reward for the successful miner consists of the transaction fees and the block subsidy, newly issued bitcoin, an amount which is halved every 210'000 blocks, approximately every 4 years. At the beginning of Bitcoin mining was done by normal computers using CPU power, later it switched to GPUs and FPGAs, and nowadays it is almost entirely done by Application Specific Integrated Circuits (ASIC)[1].

2.2 Related Work

The Bitcoin mining space is a fast-evolving and fast-growing industry. Many insights are hard to come by due to Bitcoin's decentralized nature and often rely on expert experiences in the field. The dominant Bitcoin mining ASIC manufacturers and pools are not public and pay close attention to which information is shared. This has made it hard for scientists to get reliable bottom-up data, thus often taking a top-down approach to estimate Bitcoin mining metrics.
Such an approach and often cited work comes from the Cambridge Center for Alternative Finance (CCAF) with their Cambridge Bitcoin Electricity Consumption Index (CBECI). They present an estimated historical Bitcoin network power demand and annualized electricity consumption. These estimations are based upon an estimated static global electricity price, a top-down estimation for mining hardware market share, and a static power usage effectiveness (PUE) applied to all Bitcoin miners [1]. All these top-down estimations beg the question of whether Cambridge's approach could be improved and verified with bottom-up data. Another index claiming to estimate energy consumption is Digiconomist's Bitcoin Energy Consumption Index[2] mostly based on de Vries [21]. His research has been criticized by many and his approach has been called to be of "questionable scientific rigor" [20].
Multiple market share estimations published over the past used different methodologies. In January 2020 TokenInsight published an industry research report. Their mining hardware share estimates were based on several "in-depth interviews and market surveys with the industry professionals" representing the top four manufacturers at the time, Bitmain, MicroBT, Canaan, and Ebang. We only found this report archived on Medium [18]. Not much later, in June 2020, BitMEX Research published market share by manufacturer estimates, covering the same four manufacturers. Their estimate leveraged the Initial Public Offering (IPO) prospectus of Bitmain, Canaan, and Ebang, from which the last two went public. MicroBT's presentation slides were also used as a source [15].
Last year, Coin Metrics published their research, for the first time estimating market shares and hashrates per Bitcoin mining model and therefore being the closest to our project we could find. They used an approach of analyzing nonce patterns and incorporating data sourced from real-world ASIC models [16]. With their results, they estimated Bitcoin's network-wide hardware efficiency, used the same PUE as CCAF to compare an estimated electricity consumption, and further did a e-waste estimation. Coin Metrics publishes updated figures from their research on their website[3]. We will follow similar steps, conducting several estimations comparable to these two previous results. For the scope of this project, we will stop at power demand and electricity consumption estimations.
For policy making Bitcoin's sustainability comes more and more into focus. One metric is to estimate emissions and sustainable energy use. Batten tried to improve upon CCAF's model by incorporating various data, such as off-grid Bitcoin mining [2]. Similarly, the Bitcoin Mining Council (BMC) was created in 2021 with the goal of increasing transparency, gathering data from

[1] `https://www.coindesk.com/tech/2020/04/26/the-rise-of-asics-a-step-by-step-history-of-bitcoin-mining/` [21.07.2024]
[2] `https://digiconomist.net/bitcoin-energy-consumption` [21.07.2024]
[3] Mine-Match: `https://labs.coinmetrics.io/` [21.07.2024]

the industry, and educating the public on Bitcoin mining [6]. Butterfill et al. provided valuable research before the halving this April and projected an average efficiency of 10 J/TH to be reached mid-2026 [14]. Later after the halving, they provided an update explaining their views for the future. They expect miners to shift to AI, move to stranded energy sites, and in general optimize energy costs, increase mining efficiency, and securing favorable hardware procurement terms [3]. The Bitcoin Policy Institute also expects AI compute becoming more important in this industry, however explaining the differences between Bitcoin mining and AI data centers. The former is more sustainable due to its flexibility for power grid curtailment, finding that this flexibility reduces emissions [7]. Stoll et al. analyzed 13 public miners, estimating their emissions and stating that more transparency on location and energy sources is needed to inform the public, regulators, and policymakers about the benefits and costs of Bitcoin mining in the U.S. One example is the reduction of methane emissions from orphaned and unplugged wells through Bitcoin miners [13]. Already back in 2019, they estimated a PUE of 1.05 and proposed to use IPO filings of ASIC manufacturers, insights from mining facility operators, and mining pool compositions to get bottom-up estimations improving on the existing top-down models [8]. We will pursue this approach and collect bottom-up data from the top public Bitcoin miner filings and press releases.

Chapter 3

Methodology

In this chapter, we will discuss the data acquisition process, the assisting tools used for scraping public filing documents, and press releases, and the data of interest for this study. Following up, the chosen method for completing data gaps and missing data is discussed. Lastly, we mention the calculations we made to get to our estimations, which will be the main focus of chapter 4.

3.1 Data Acquisition

A bottom-up approach is chosen to collect data on the distribution of ASIC hardware models in the Bitcoin mining industry. This industry distributed around the globe, consists of individual, private, and public miners. The latter, meaning publicly traded Bitcoin mining companies, are required to disclose data for transparency and to inform investors about their financial statements and business practices. Public companies represent a significant portion of Bitcoin's hashrate and aggregated data from their public filings can be updated over time. The most common updates come in the form of quarterly reports and more detailed yearly reports, but some companies also publish additional press releases every month or to announce key events.

The public filing documents are found on the public company's website in the investor relations section or can be accessed directly through the securities overseeing agency for the respective stock market. For the biggest capital market, the U.S. stock market, that is the U.S. Securities and Exchange Commission[1] (SEC) and marked on websites as SEC filings. Wherever possible, we opt for the public miner's website and download quarterly and yearly filings in Portable Document Format (PDF). We use OpenAI's large language model GPT-4 for keyword extraction from these PDFs and use these keywords to find the locations of interest in the filing documents with the keyboard shortcut function Control Find. To check for further information GPT-4's online search function is used and the press releases are skimmed.

An extensive list of public Bitcoin miners is put together starting with previous work done by Braiins[2] and extending it with additional and up-to-date entries from TheMinerMag[3], Luxor's Hashrate Index[4] or other ranking websites[5]. The official company name and ticker symbol are collected for unique and quick identification.

The data of interest are the reported hashrate, the size of the mining fleet, and the number of mining rigs per hardware model. For the given hashrate values, we make sure to keep the distinction between electrified and installed hashrate, wherever indicated. We also differentiate

[1] `https://www.sec.gov/search-filings` [21.07.2024]

[2] `https://braiins.com/` [21.07.2024]

[3] `https://pro.theminermag.com/overview` [21.07.2024]

[4] `https://data.hashrateindex.com/stocks` [21.07.2024]

[5] `https://companiesmarketcap.com/bitcoin-mining/largest-bitcoin-mining-companies-by-marketcap/` [21.07.2024]

hashrate from self-mining and hosted machines. If no specification is given on the reported hashrate, we mark it as such. See appendix B.1 for a closer look at the database with the companies' hashrates. We collect the fleet and hardware model numbers in a separate database. For the size of the mining fleet, we make notice if the company gives additional specifications. We find, that we again have to distinguish between hardware units, which they own and use for self-mining, and other hardware units, which they use for hosted mining. Additionally, some companies report distinct values for deployed versus total mining fleets. A few even mention the number of mining rigs in storage or transit.
The most important data for this project is the number of mining rig units per ASIC hardware model. Here we store, whenever mentioned the hardware manufacturer and model. Then for every quarterly filing and press release, we collect how many units were installed, how many are expected to be installed because of published purchasing agreements and options, and how many have been removed. If only the manufacturer is known, the model name is given as unknown. If even the manufacturer is unknown, for example when just a number of mining rigs is mentioned, both are marked as unknown.
This data sets the basis for this project's analysis. Due to the requirements of publication, mostly financial data and therefore purchase agreements and options are found in the quarterly and yearly filings. These agreements do not have to represent the future, can be sold to another mining company, can have delays and updates, which makes the tracking of actual mining rig numbers much more challenging. Also, public companies are not required to publish the number of their fleet. For transparency, the total hashrate is published, which is also of interest to the investor, but specific mining units only show up in assets under management or to lay out the risks coming with a Bitcoin mining strategy. Therefore, the data is by no means complete and covers the analyzed range in a quarter granularity. Have a look at the hardware database in appendix B.2.

3.2 Data Completion

We want to complete the data extracted from the publicly available resources in such a way, that we can get an estimated development of total hashrates and an estimated distribution of ASIC hardware models of public Bitcoin miners. Here are the assumptions we make and the rules we follow to complete the companies' hashrate values.

Type	**Rule**	**Comment**
reported	remains constant in the future until a new value is reported	-
electrified	cannot be completed	calculate further with installed hashrate
installed	remains constant in the future until a new value is reported	-
self-mining	remains constant in the future until a new value is reported	-
total	remains constant in the future until a new value is reported	contains hosted hashrate, calculate further with self-mining hashrate

Table 3.1: Assumptions for Completing the Hashrate Values

Some companies give an outlook on expected FUTURE hashrate. Since the company's yearly results are the main focus, this outlook in general refers to end-of-year values, in our case to the fourth quarter of 2024 (24Q4). In some cases, the outlook is given for larger time frames, and the expected future hashrate value seams to be more in line with the next four-year Bitcoin

cycle. This FUTURE hashrate is kept constant if no outlook is given and the self-mining to total mining ratio is respected if only a partial outlook is given.
Similar assumptions have to be made to complete the hardware data and the rules we applied are listed here.

Type	**Rule**	**Comment**
model	number of units are set at zero as long as there are no mentions	-
model	number of units are kept constant as long as there are no updates	broken hardware is not considered
model	notable or mentioned sell-offs of old hardware are set to zero after these models are not mentioned anymore	-
model	future number of units is kept constant if no outlook is given	-
total	total number of units are set at zero as long as there are no mentions	-
total	total number of units are kept constant as long as there are no updates	broken hardware is not considered
total	future total number of units is kept constant if no outlook is given	-

Table 3.2: Assumptions for Completing the Hardware Numbers

The total number of units refers here to explicitly mentioning fleet size and is not a summation of the single hardware model numbers. This way, we have a way to check if all number of different mining rig models are give completely and to check how good our estimation fits with the reported fleet size.

3.3 Calculations for the Estimations

Using our database, we can continue with some basic calculations for our analysis. In addition to the gathered data, we need the hardware models release dates, which we get from Luxor's Hashrate Index[6] and from ASICMinerValue[7]. From the same sources, we also get the ASIC miner hashrate given in terahash per second $[TH/s]$, and their respective efficiency given in joule per terahash $[J/TH]$. This is the unit of measurement for efficiency, most commonly used in the Bitcoin mining space, and means the energy used for a trillion SHA-256 operations, which is implicitly always given on a per-second basis[8]. We will use the common notation for this project. For future research, we recommend using CCAF's CBECI SHA-256 Mining Equipment List in the Miner Hardware Inventory Database[9] which is being updated from time to time and where suggestions for updates can be contributed from interested parties.

Four estimations can be made with the gathered data. Each of them can be shown in terms of hardware models or manufacturers.

[6]`https://hashrateindex.com/rigs` [21.07.2024]
[7]`https://www.asicminervalue.com/efficiency/sha-256` [21.07.2024]
[8]Physically it is given in joule per terahash per second $[J/TH/s]$ or in joule-seconds per terahash $[J \cdot s/TH]$, using the unit of action.
[9]`http://sha256.cbeci.org/` [21.07.2024]

Firstly, we transform our hardware database from "sorted by company" to "sorted by ASIC hardware model". So we add up all the numbers for each model and do this for every quarter in the investigated time range. This is also possible for the total hardware fleet numbers we collected. The numbers we get can easily be summed up to a number of hardware units per manufacturer, which again can be summed up to an estimated total. This estimate can then be compared to the summation of total hardware fleet numbers.
More important and of bigger interest is not the number of units but the hashrate for each model for every quarter. So secondly, we multiply the number of units found before with the hashrate given in the miner model specifications. For unknown models, but by known manufacturer, we take the average installed hashrate of all other models by the same manufacturer and multiply it by the number of unknown units. For completely unknown models we do the same, taking the average installed hashrate over all models and manufacturers. Doing this for every quarter counts unknown models to estimate hashrates. As current ASIC SHA-256 miners come with a hashrate from 10 to 300 TH/s, and we add up thousands of units, we divide the numbers by 1000 to get petahash per second $[PH/s]$. 1 PH/s is a quadrillion computations per second. We use an estimate of Bitcoin's global hashrate[10] on every last day of every quarter and change it from the usual representation in exahash per second $[EH/s]$, a quintillion computations per second, to $[PH/s]$. As mentioned on Blockchain.com's website, Bitcoin's exact global hashrate is unknown but can be estimated from the number of blocks found in the current difficulty period. Again we can add the resulting hashrates up to get hashrates per manufacturer and an estimated total hashrate (by public Bitcoin miners). This estimate can again perfectly be compared to the summation of reported hashrates.
Thirdly, we can use the found hashrates and calculate hashrate shares by hardware model and per manufacturer. The estimated total hashrate and the reported total hashrate are set in relation to the global hashrate. This gives the important estimated percentages of analyzed hashrate, which will be useful for interpreting the results.
Lastly, given the hardware model efficiencies, we can calculate power demands per hardware model and aggregated power demand per manufacturer. The former is found by multiplying the hardware model's hashrate $[PH/s]$ by the respective efficiency $[J/TH]$, from the miner models' specifications. Keeping track of unit conversions, these estimates are best given in megawatt $[MW]$. Again, for unknown hardware models, we take the average installed efficiency by manufacturer and if even the manufacturer is unknown, we take the average installed efficiency over all models and manufacturers. This in itself is an interesting value to track quarterly and we will discuss it later.
Having done all these calculations, we now have estimates for number of units, hashrate values, share percentages, and energy values. The estimated power demand values and especially the estimated aggregated power demand might induce oneself to do the seemingly small step of an extrapolation to Bitcoin's global power demand. That would be to divide the estimated power demand by the estimated percentage of global hashrate multiplied by an estimated global PUE. We will discuss the problems with this extrapolation in chapter 4.

[10] `https://www.blockchain.com/explorer/charts/hash-rate` [21.07.2024]

Chapter 4

Results

This chapter presents the results we get from the public Bitcoin miner data. We collected 49 company names and their ticker symbols that showed up in Bitcoin miner stock market lists, were kept track of in previous research from Braiins, or had other connections to Bitcoin mining in any shape or form. Of these, we gathered data from the 28 largest companies about their installed hashrate and from almost all of them we found data on fleet size and number of ASIC hardware models. Namely, they are the following, sorted by descending hashrates.

Company Name	**Ticker**		
Marathon Digital Holdings Inc.	MARA	Canaan Inc.	CAN
BitFuFu Inc.	FUFU	Northern Data AG	NB2
Core Scientific Inc.	CORZ	Galaxy Digital Holdings Ltd.	GLXY
CleanSpark Inc.	CLSK	Argo Blockchain PLC	ARBK
Riot Platforms Inc.	RIOT	Soluna Holdings Inc.	SLNH
Iris Energy Ltd.	IREN	Ault Allinace Inc. (BitNile)	AULT
Bitdeer Technologies Group	BTDR	Digihost Technology Inc.	DGHI
Terawulf Inc.	WULF	Sphere 3D Corp.	ANY
Cipher Mining Inc.	CIFR	Greenidge Generation Holdings Inc.	GREE
Hut 8 Corp.	HUT	DMG Blockchain Solutions Inc.	DMGI
Bitfarms Ltd.	BITF	Gryphon Digital Mining Inc.	GRYP
HIVE Digital Technologies Ltd.	HIVE	SATO Technologies Corp.	SATO
Stronghold Digital Mining Inc.	SDIG	Cathedra Bitcoin Inc.	CBIT
Bit Digital Inc.	BTBT	Mawson Infrastructure Group Inc.	MIGI

Table 4.1: List of Public Bitcoin Miners

For the remaining 21 companies, one or multiple of the following points moved us to not consider them further in the scope of this semester project. Nevertheless, they are listed in the database and can be included in future research.

- no mention of Bitcoin mining
- no publicly available filings with usable data
- manufacturers or distributors of ASIC hardware, giving no detail on mining operations[1]
- too small (in the low PH/s range) to collect significant data from

[1] It is known that Bitcoin mining hardware manufacturers can be operating self-owned machines [17].

Our database covers data from over two years back with a granularity of 3 months. This aligns with the publication dates for quarterly and yearly filings. The database is constructed so that future quarterly data can be added. We will use the following notation, as shown in table 4.2.

Notation	**Refers to ...**	**Filing Date**
21Q4	Fourth quarter data of 2021	31.12.2021
22Q1	First quarter data of 2022	31.03.2022
22Q2	Second quarter data of 2022	30.06.2022
22Q3	Third quarter data of 2022	30.09.2022
22Q4	Fourth quarter data of 2022	31.12.2022
23Q1	First quarter data of 2023	31.03.2023
23Q2	Second quarter data of 2023	30.06.2023
23Q3	Third quarter data of 2023	30.09.2023
23Q4	Fourth quarter data of 2023	31.12.2023
24Q1	First quarter data of 2024	31.03.2024
24Q2	Second quarter data of 2024 (no data available as of project due date)	30.06.2024
FUTURE	Q4 of 2024 or any future outlook data given by the companies	-

Table 4.2: Notation

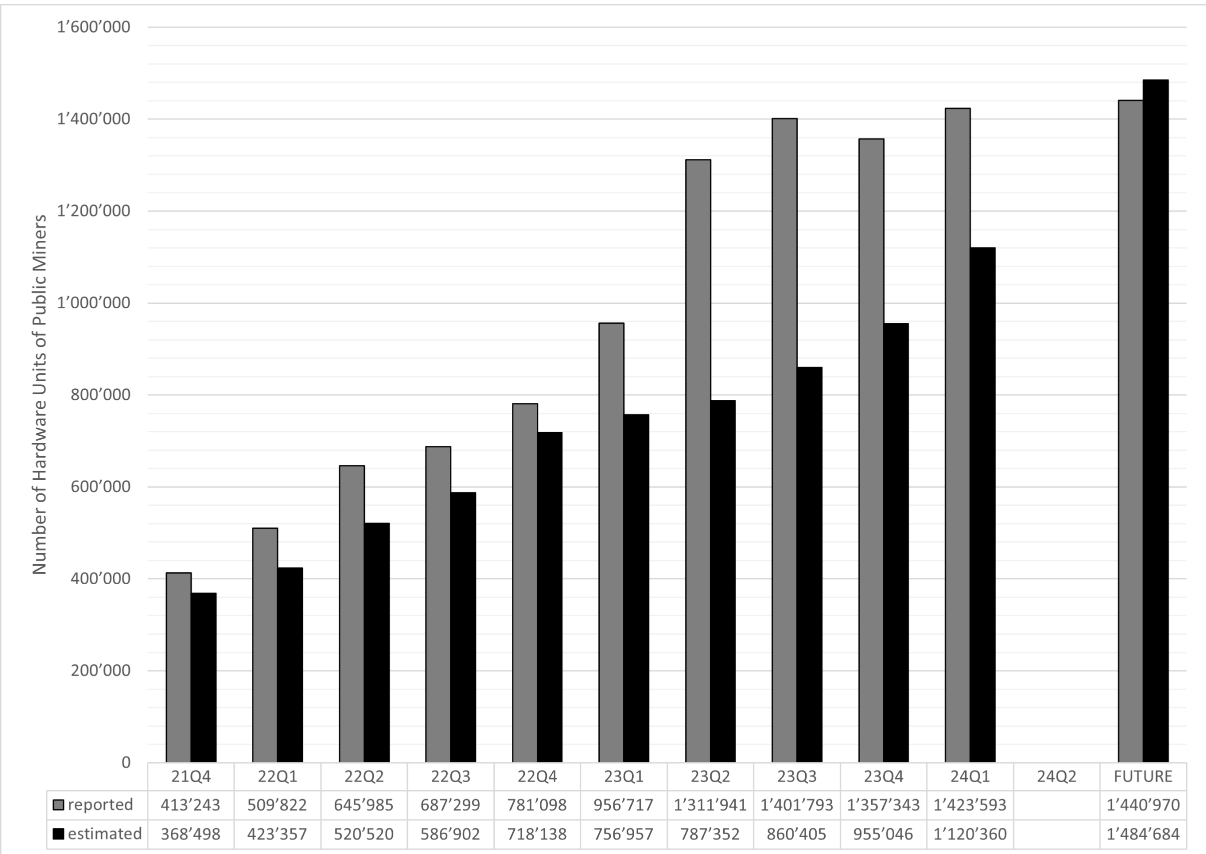


Figure 4.1: Total Number of Hardware Units

4.1 Number of ASIC Hardware Units

Strait from the hardware database B.2 we sum up the number of ASIC hardware units every quarter. We differentiate between the aggregated *reported* numbers we get, and the *estimated* numbers we get by adding up all the hardware model amounts. Comparing these two in figure 4.1, we see that they go well in tandem throughout 2022, with our estimate only being around 10 to 20% below the reported values. In 2023 this changes to a difference of around 30 to 60%. This could be caused by different reasons such as a change in disclosure requirements by the SEC, the crackdown on crypto-related activities by the SEC, or market dynamics and risks causing the miners to provide less detailed information. Only the last of these reasons, we think could have affected specifically Bitcoin mining companies around that time, since lower Bitcoin prices during the bear market pushed hashprice[2] down to new lows and pushing down miners profitability. At the same time, the companies focused on streamlining their business, so they would survive the Bitcoin Halving coming up in April 2024. For the future outlook, the reported and estimated number of units align again quite well. This is however caused by our methodology and companies giving more information on future purchasing agreements and options for single hardware models. These will be counted in our estimated value, but not in the reported expected size fleet. Such a number is rarely published by the public miners.
We approximate, from these numbers of installed hardware units and take into account older hardware units which are taken offline (see negative values in the database B.2), that 34'500 units are being installed and around 1'800 units are being decommissioned per month by these public miners.

4.1.1 Units by Manufacturer

Now we take a closer look at the partitioning of these hardware units between Bitcoin mining ASIC manufacturers. Hardware units, which we could not assign to a specific manufacturer, are shown as *unknown* in figure 4.2. As described before, *TOTAL* refers here to the reported number of units. Clearly, *Bitmain* followed by *MicroBT* have produced one order of magnitude (logarithmic chart) more hardware units, used by public Bitcoin miners. *Canaan* comes in at a smaller third place. We think that the unknown hardware units fall under one of these three manufacturers. Especially since all analyzed companies, where we found numbers, were using Bitmain Antminers except for two. One is solely mining with MicroBT Whatsminers, and the other is Canaan Inc. itself, which is mining with Canaan machines.
Nevertheless, it is also visible that more companies are entering the market. These are *Intel Blockscale*, *MinerVA*, *ePIC Blockchain*, and *Bitdeer*. Bitdeer is a public Bitcoin miner, has its own miner, the SEALMINER, on the market, and announced a roadmap for its new ASIC chip designs [9]. We have not found any numbers of deployed SEALMINERs therefore it does not show up on the chart 4.2. *Innosilicon* hardware models we found, have been pushed out of the market due to low profitability [19]. They have produced newer and more profitable models, such as the T4+ [11], but we have not found deployment numbers. So the number drops to zero. The biggest increase in future expected number of hardware units is by far Bitmain. This increase, see figure 4.3, is mainly driven by big purchase agreements and options, that are known.
Experts in the Bitcoin mining field estimate that 50'000 rigs are produced by the main manufacturers per month. Hashrate Index reported in September of 2023 from a Bitmain representative, that "the company expects to manufacture at least 50,000 units per month [...] for the next 8 months, but the company may produce as many as 100,000 per month if there is sufficient demand" [10]. We approximate, that 19'300 Bitmain Antminers have been deployed per month by our analyzed public companies. If we look ahead and calculate with the estimated hashrate

[2] `https://data.hashrateindex.com/network-data/btc` [21.07.2024]

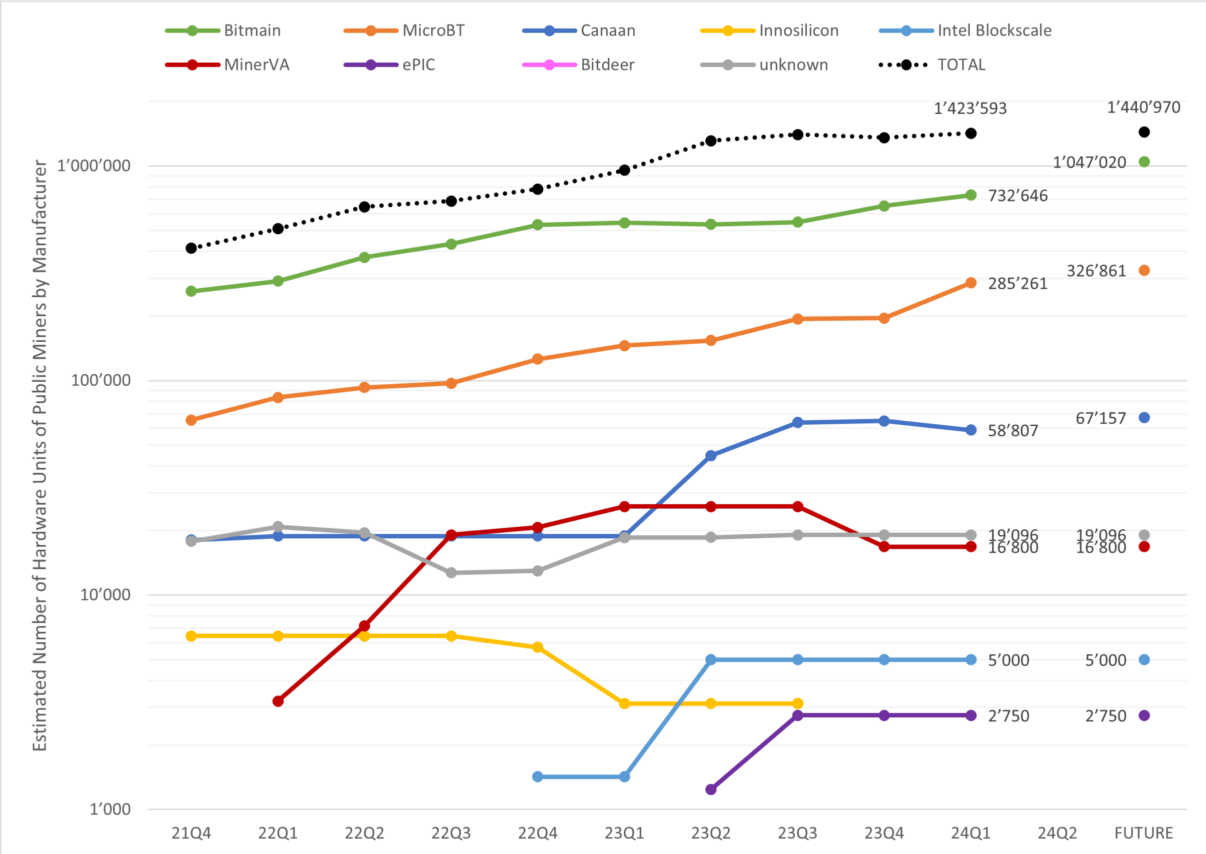
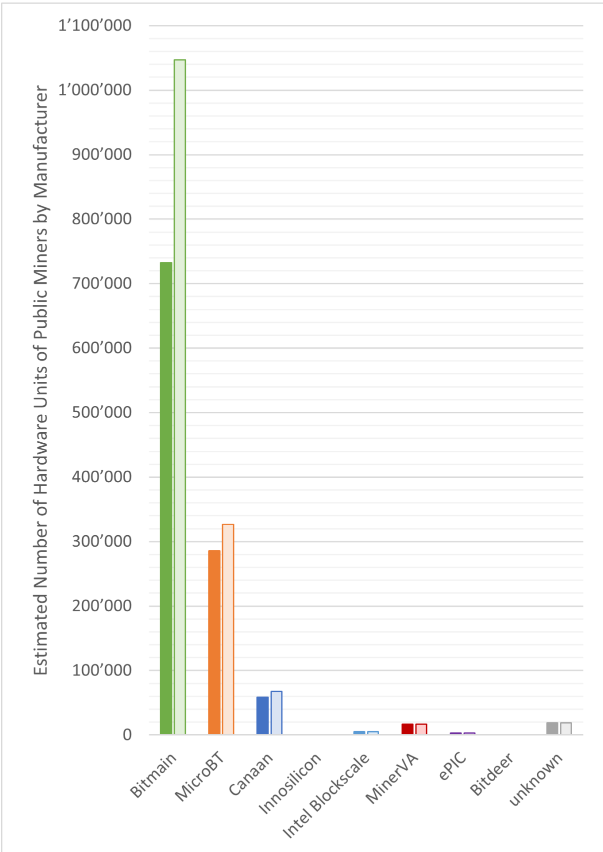


Figure 4.2: Number of Hardware Units by Manufacturer

share, discussed in section 4.3, we could approximate that 63'000 to 95'000 Bitmain units have been deployed monthly over our analyzed period. It lies perfectly in the range given by the sources and indicates that these numbers are correct for the manufacturer Bitmain. For the second main manufacturer MicroBT, the same calculation would approximate 4'000 MicroBT Whatsminers deployed per month by our analyzed public companies, and in total 13'300 to 20'000 Whatsminers. But here, and for the remaining manufacturers we have no numbers to compare this to.

4.1.2 Units per Model

Looking at the number of units deployed per model is less informative than the hashrate findings we discuss in subsection 4.2.2. Still, one insight can be extracted from the 55 mentioned hardware models that we found. Newer hardware models are produced and later deployed in larger quantities as demand seems to be around for these generally more efficient machines. The Bitmain Antminer model generations deployed the most, S17, S19, and S19j Pro found their peak number of deployment in 22Q1, 22Q3, and 23Q1 respectively with 15'034, 108'456, and 207'153. The newer Antminer models are still ramping up with 203'820 units in 24Q1 for the S19 XP and 236'268 units of the S21 expected to be deployed. The same holds for MicroBT's M10, M20, M30, M50 and M66 Whatsminer generations, and Canaan's A1166, A1246, A1346, and A1466 Avalon generations.



left (dyed) 24Q1, *right (framed)* FUTURE

Figure 4.3: Outlook on Number of Hardware Units by Manufacturer

4.2 ASIC Hardware Hashrates

In this section, we will look at the estimated resulting hashrates. These hashrates are the computational powers of ASIC Bitcoin mining hardware by public Bitcoin miners. All the deployed models we found in the public filings and press releases are ASIC machines. These fast, efficient, and Bitcoin-specific ASICs have surpassed CPUs, GPUs, and FPGAs in profitability for over a decade. All the following results are estimates because of two main reasons. First, we calculated that all installed mining rigs are operated with 100% up-time, and operated the nominal hashrate. In practice, deployed machines need maintenance and sometimes repair, can be over- or underclocked, and can be turned off for other reasons such as power grid stabilization in an ancillary service curtailment program as a large flexible load [13]. Second, our research only covers the 28 biggest public Bitcoin mining companies and can therefore be regarded more as a lower bound, than the total hashrate deployed by public miners.
Figure 4.4 compares the aggregated *reported* and the *estimated* total hashrate of the public miners to Bitcoin's global hashrate. Reported refers to the hashrates published by the companies and estimated refers to the summed-up hashrates found for every hardware model, also published by the same companies. Both increase steadily, as Bitcoin's hashrate also does from 21Q4 to 24Q1. The global hashrate reached a high of over 600 EH/s around 24Q1 and dropped slightly in 24Q2. We do not have values for that quarter at the time of this project. Nonetheless, the public miner hashrate is expected to increase in the future. We see a similar difference, as in the total number of units, between the reported and the estimated hashrate. This could be caused by a change in publication transparency or reported hashrates being overstated as an important marketing tool. Which share of global hashrate we cover here, is discussed in section 4.3. More charts for this section are in the appendix C.3.1.

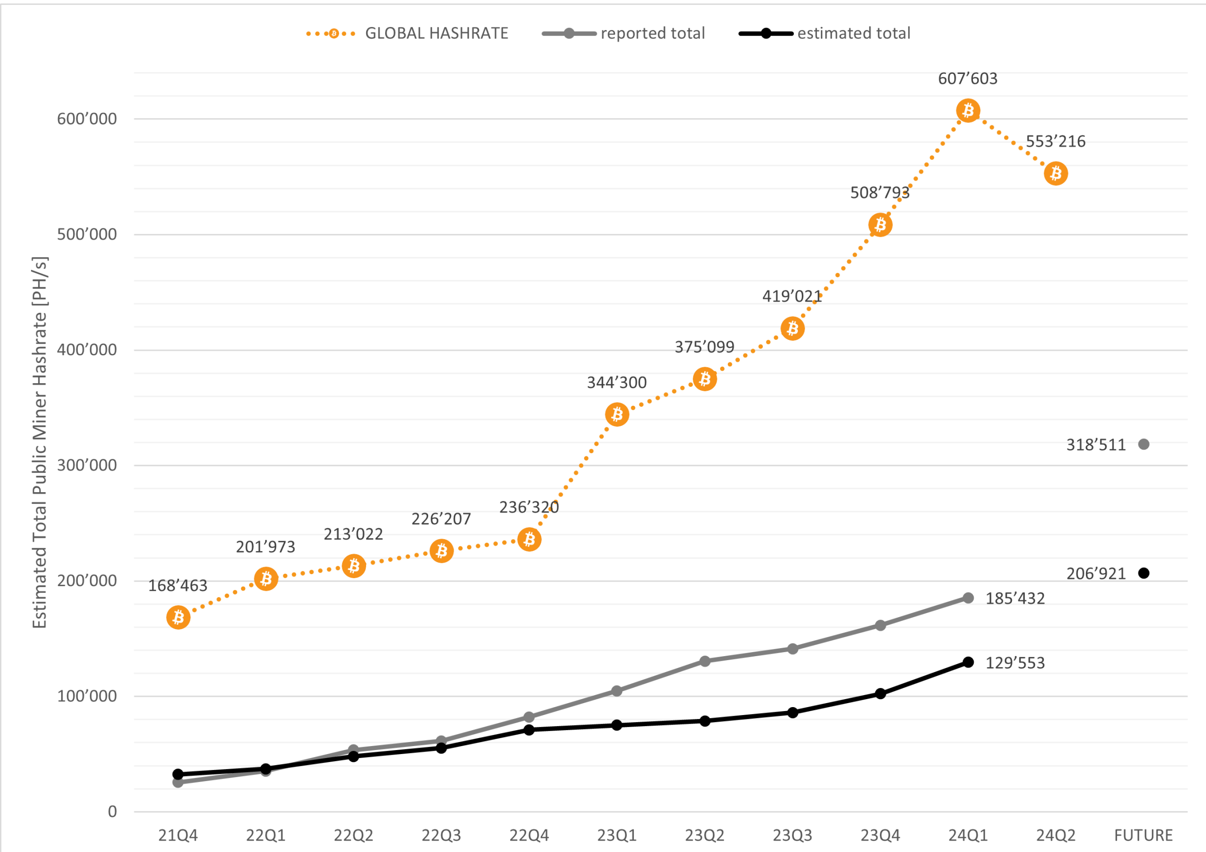


Figure 4.4: Total Public Miner Hashrate vs. Bitcoin's Global Hashrate

4.2.1 Hashrate by Manufacturer

We now dive into the hashrate results with a higher resolution, split into manufacturers. For this, we consider the estimated hashrates only. Also here, see 4.5, is an exponential increase in hashrate visible, with an average increase of about 16.61% per quarter, or 5.25% per month over the analyzed period. Following this growth trajectory would align with the estimated future outlook hashrate around 24Q4. The entire public miner hashrate comes almost from hardware from three manufacturers only, with *MicroBT* and especially *Bitmain* producing the lion's share of computational power. As of the end of the first quarter of 2024, 87.8 EH/s of the public miners came from Bitmain Antminer machines, 30.7 EH/s from MicroBT Whatsminer machines, and 6.2 EH/s from Canaan Avalon machines. We will discuss the actual shares per manufacturer in the following section 4.3.1.

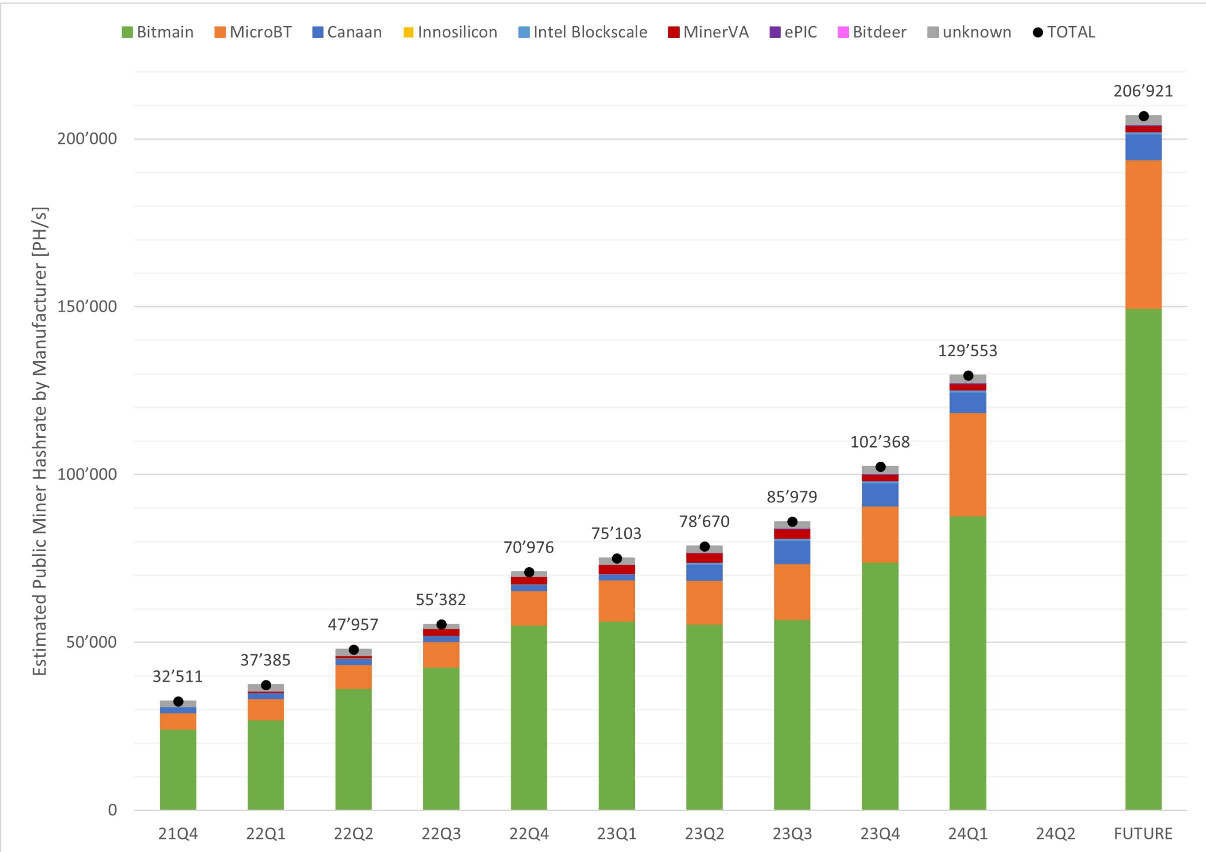


Figure 4.5: Distribution of Hashrates by Manufacturer

4.2.2 Hashrate per Model

Next, we find out what hashrates single Bitcoin mining hardware models contribute. We see that not just a few manufacturers dominate but also only a few hardware models dominate over some periods. We try to showcase this in figure 4.6.

Ahead of all was always a Bitmain Antminer machine *(green)*, starting with the Antminer *S19*, followed up by the *S19j Pro*, which then was overtaken by the *S19 XP*. Each takes over with a higher total hashrate per model. The S19 XP almost reached 30 EH/s in 24Q1. Other significant Bitmain ASIC rigs worth mentioning are the Antminer *S19 Pro* and the Antminer *S19j*. Continuing with Bitmain hardware models, we see that the newer models Antminer *S19k Pro*, *S21*, *T21*, and particularly the *S19j XP* are starting to pick up pace, increasing their

hashrate. If we now compare 24Q1 in figure 4.7 with the outlook in figure 4.8, we spot that the S21 is expected to surpass the S19 XP reaching up to 50 EH/s, and the T21 also picking up reaching a comparable hashrate to the S19j Pro. Another visible point is that older and less efficient hardware units with lower profitability are driven out of the market, often replaced by a newer model. A good example of this could be the Antminer S19, losing hashrate around the same time as the Antminer S19 XP gains in hashrate. Our analysis of over two years is too short to see how long a single hardware miner is deployed profitably. We think this is also linked with Bitcoin's four-year cycles, which have a strong impact on hashprice[3]. Still, we see that the dominant hardware model is in its position for about one and half years before being overtaken by the next generation hardware model.
MicroBT Whatsminer machines *(orange)* show similar occurrences and distributions. During this period the Whatsminer *M30S* has the highest hashrate, reaching about 8 EH/s in 23Q3. 6.5 EH/s distribute among the other Whatsminer from the *M30*, *M31*, and *M32 series*. In the chart 4.6 only the *M30S+* can be distinguished. Also here we see that the newer models Whatsminer *M50* and *M56++* pick up pace, increasing their hashrate. Comparing again figure 4.7 with the outlook 4.8, we see that the even newer and more efficient Whatsminer *M66S* and the *M66* are expected to grow the most in deployed hashrate. The former is expected to surpass the M30S reaching over 14 EH/s. So this takeover process is expected to continue in the future, especially if these two conditions are being met:

- production of newer hardware models continues to increase
- efficiencies of newer hardware models continue to increase

The distribution in the hardware models that produce less hashrate follows the same trend and outlook, as seen for Bitmain Antminers and MicroBT Whatsminer. This can be seen in logarithmic charts, C.10 and C.11, added in the appendix.
We get a good estimated overview of deployed hashrates per hardware model by looking at figure 4.9. Older hardware stagnates and later decreases in hashrate. Newer hardware comes with more hashrate, and gains quickly in market share, continuing the exponential increase in hashrate. Next to already discussed Bitmain's *(green)* a MicroBT's hashrate *(orange)*, also Canaan's *(blue)* and MinerVA's *MV7* deployed hashrate are visible. The public resources we use do not specify a large portion of the Canaan Avalon hardware rigs, now showing up as an estimated hashrate *unknown (light blue)*. 1 to 2 EH/s *(gray)* are a rough estimation for hashrate hardware units which were mentioned in the public resources, but not at all specified in terms of model and manufacturer.
Overall, our data depicts trends over 27 months. This is less than the length of a Bitcoin cycle, which takes about 4 years, and new epochs heralded by the Bitcoin halving events. These halvings affect Bitcoin miners, especially in the early years of Bitcoin and none of these occurred during the analyzed period. So these trends happened during a Bitcoin price bear market and can only be expected to continue if this analysis is continued over at least one cycle.

[3] `https://data.hashrateindex.com/network-data/btc` [21.07.2024]

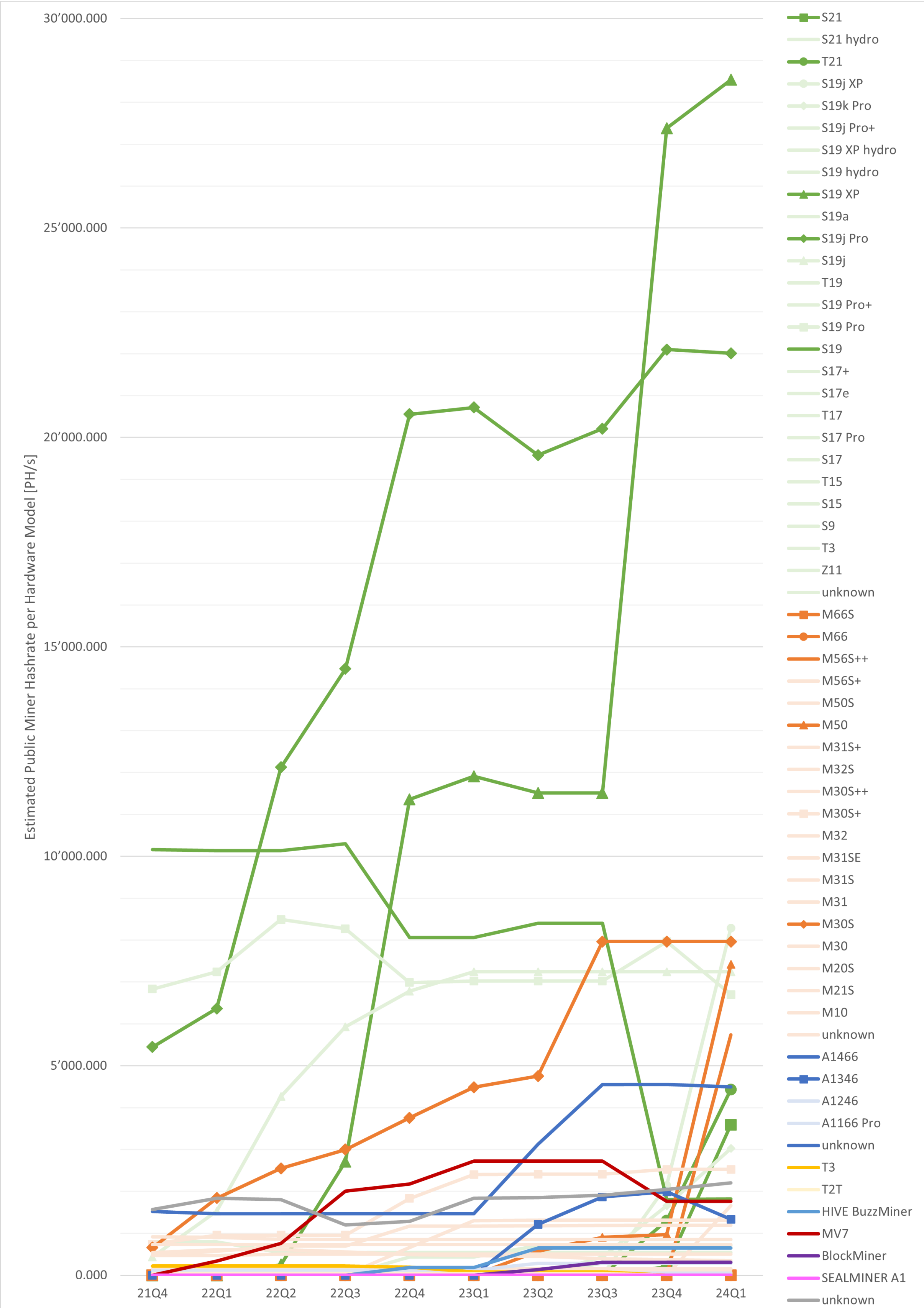


Figure 4.6: Hashrate per Hardware Model

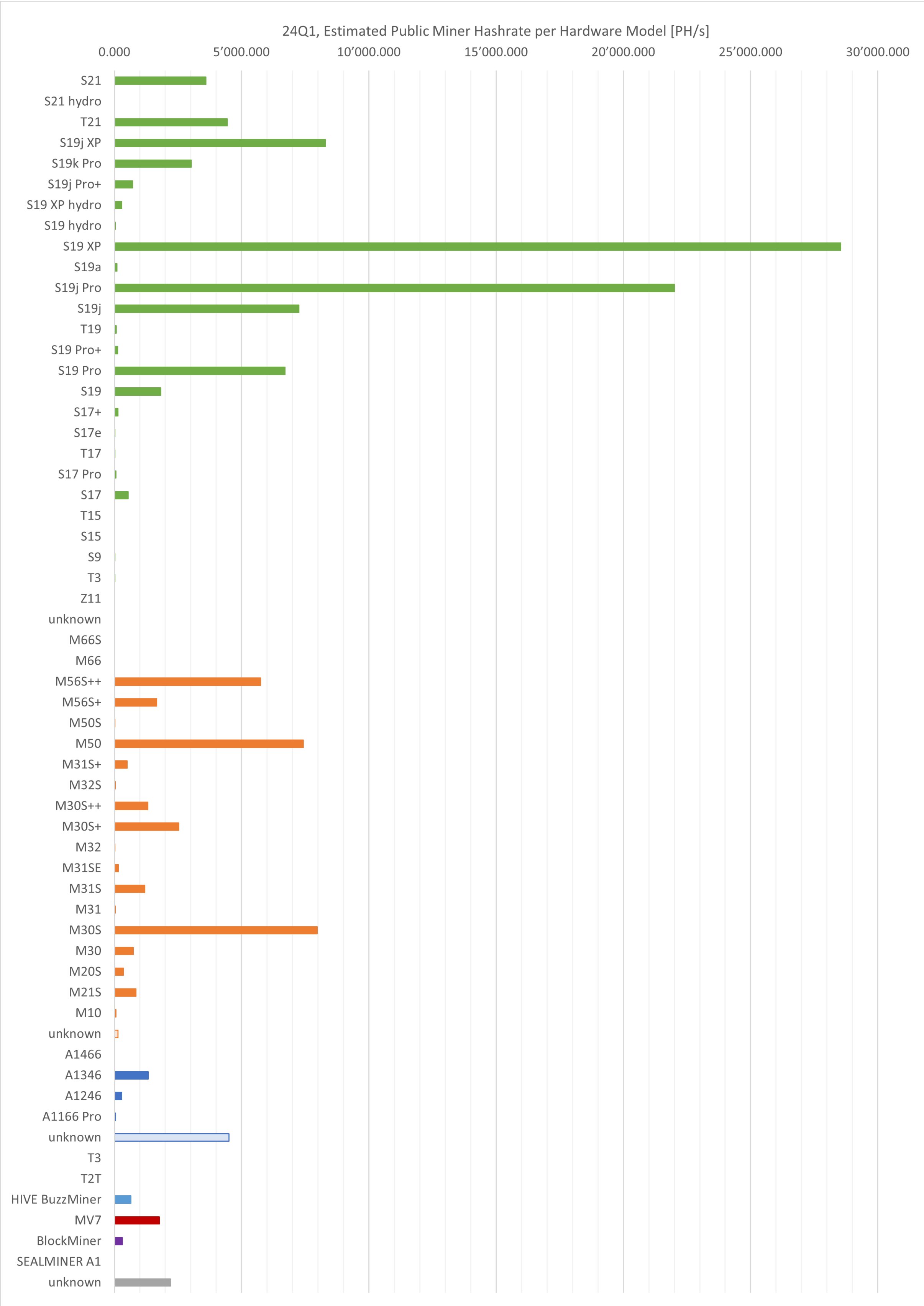


Figure 4.7: First Quarter of 2024 Hashrate per Model

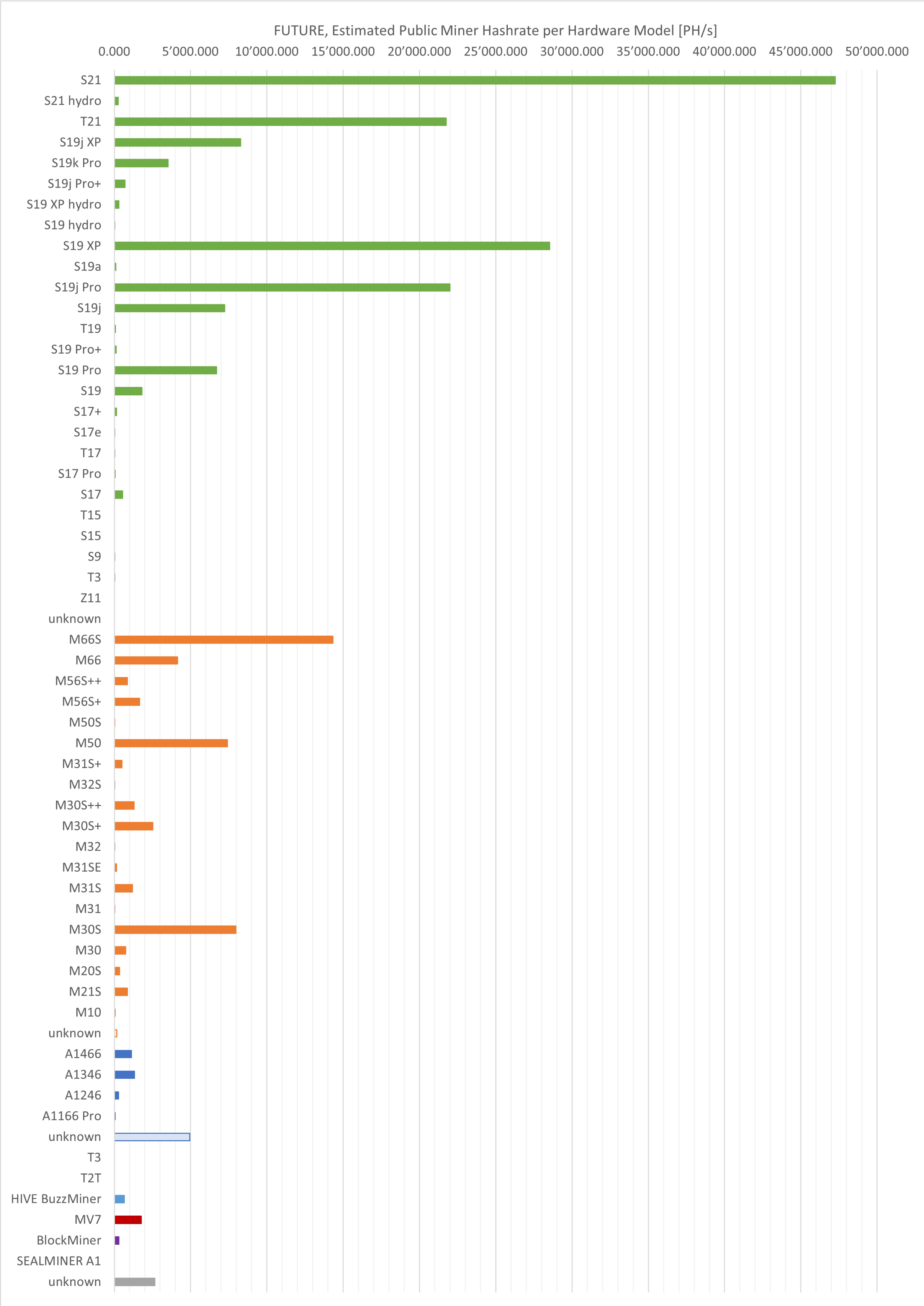


Figure 4.8: Outlook on Hashrate per Model

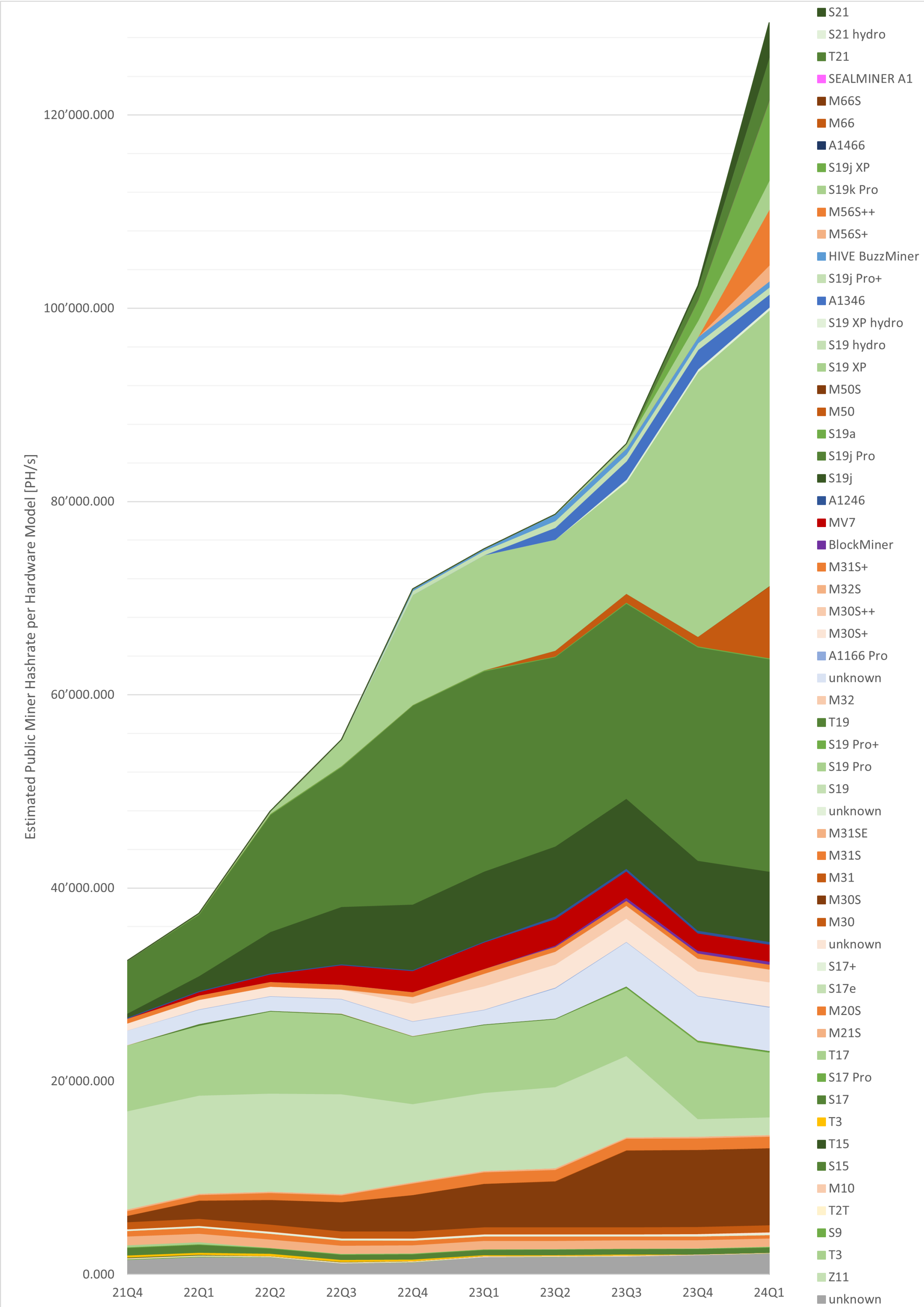
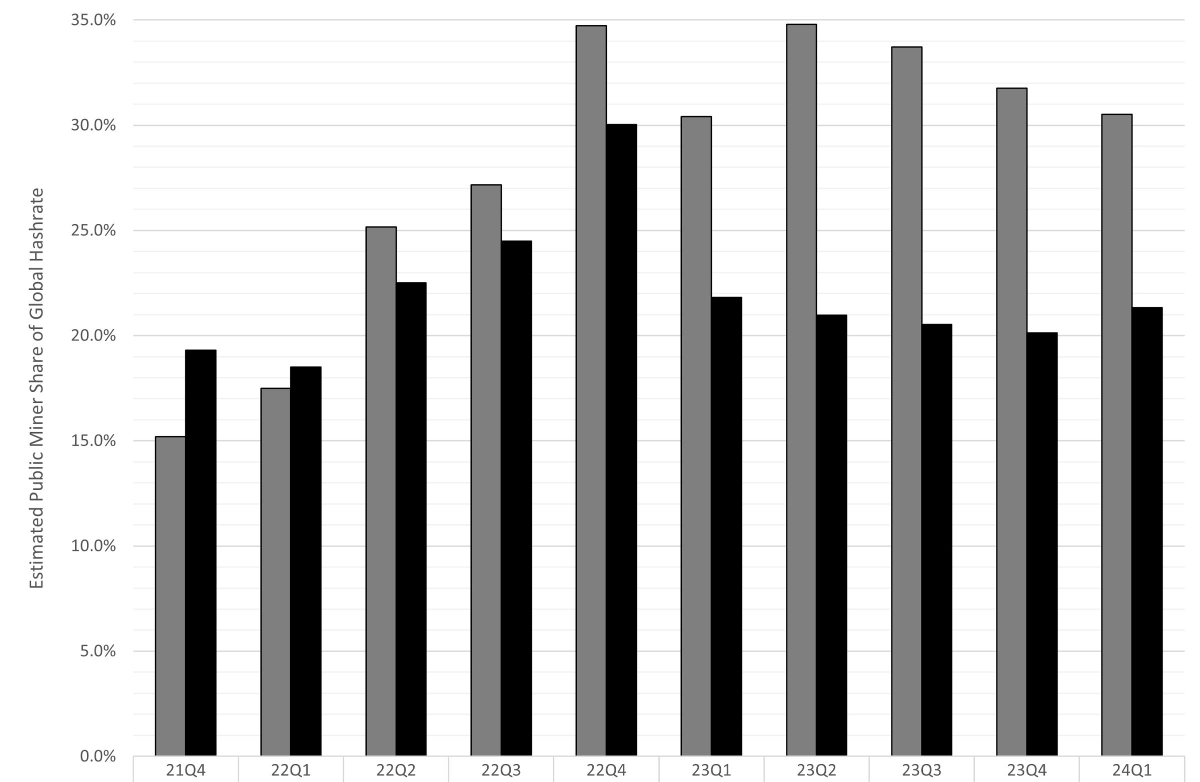


Figure 4.9: Aggregated Hashrate per Hardware Model

4.3 ASIC Hardware Shares

Finally, we look at our results in percentage terms. This helps strengthen the understanding of the data collected and assists in assessing the scope, in which the results can or cannot be interpreted. As a reminder, we gathered data from the biggest and noteworthy 28 public mining companies. We aggregated the number of mining rigs and fleet sizes. From there we estimated hashrate values. In this chapter, we relate these hashrates to Bitcoin's global hashrate, which is in itself an estimation. Assuming public miners represent similar mining hardware distributions as the rest of the network - and that's an important assumption - the following shares can be interpreted as shares representing the entire Bitcoin hashrate.
We find that these public miners have on average 28% of the global hashrate if we use their *reported* hashrate values. From our *estimated* hardware hashrates, we get more detail on an average of 22% of the global hashrate over the analyzed period. We think this can be seen as a lower bound for public miner hashrate and that over a third of Bitcoin's hashrate stems from public miners. In figure 4.10 we see the percentages increase until 2023, then stagnate and slightly retract into 2024. The rise could be explained by more and more companies coming online and our methodology collecting more and more of that data. Since we only looked at a fixed amount of companies, competition still increases between public and private companies, keeping the shares constant or pushing them down.



	21Q4	22Q1	22Q2	22Q3	22Q4	23Q1	23Q2	23Q3	23Q4	24Q1
reported	15.2%	17.5%	25.2%	27.2%	34.7%	30.4%	34.8%	33.7%	31.8%	30.5%
estimated	19.3%	18.5%	22.5%	24.5%	30.0%	21.8%	21.0%	20.5%	20.1%	21.3%

Figure 4.10: Public Miner Share of Bitcoin's Global Hashrate

We kept track of reported *self-mining* hashrates and reported total hashrates. Companies disclose if they are hosting machines, whose hashrate is included in the total. Hosted Bitcoin mining can come from private ASICs hardware or even mining rigs from other public companies. As an example, Hut 8 Corp. (*public*) hosted miners for Marathon Digital Holdings Inc. [4] (*public*) and for Ionic Digital [5] (*private*). Therefore, the total reported hashrates should not be included in our estimation to avoid double accounting. That way we estimate around 80% of self-mining being done by public miners, and respectively 20% being hosted mining. The lack of data in the first couple of quarters lets us only display this estimation from 23Q2 onwards, see figure 4.11.

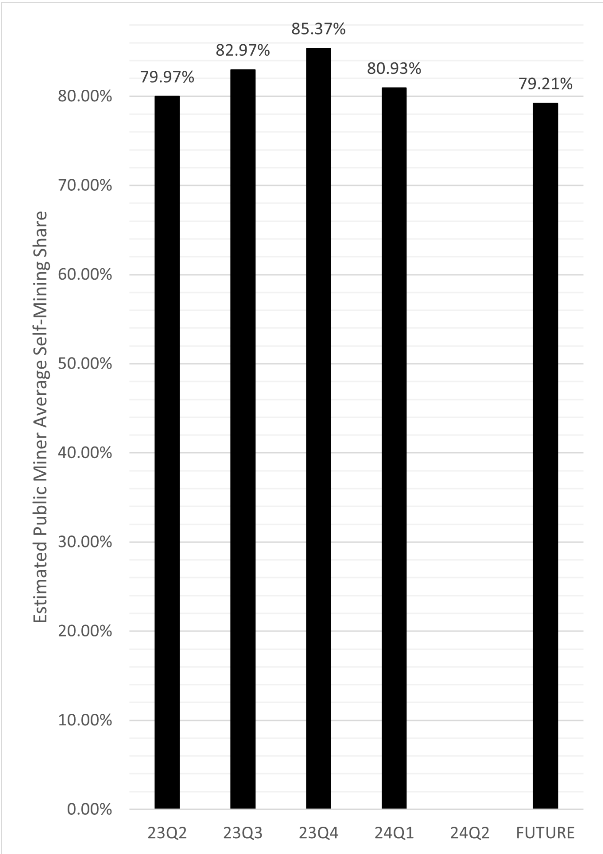


Figure 4.11: Average Self-Mining Share

4.3.1 Share by Manufacturer

The shares remain almost constant over time when displaying the hashrate market share by manufacturer, figure 4.12. *Bitmain* and *MicroBT* have a remarkable share of 72.8% and 16.8% over this period. This is not expected to change much in the future. Considering that a similar share of the *unknown* mining hardware also stems from these two companies, we can say that they formed a duopoly of 92.1% between 21Q4 and 24Q1.
The rest is comprised by the other manufacturers, visibly *Canaan* and *MinerVA*. Their percentages decrease looking at the companies' outlooks, figure 4.13. That is probably caused by more big Bitmain Antminer and MicroBT Whatsminer purchase agreements and purchase options being reported and captured by our methodology. Continuing this research for further and upcoming quarters should shine a light on more hashrate, the more companies are being tracked, and generally, reduce the slice of hardware not classifiable by manufacturer.

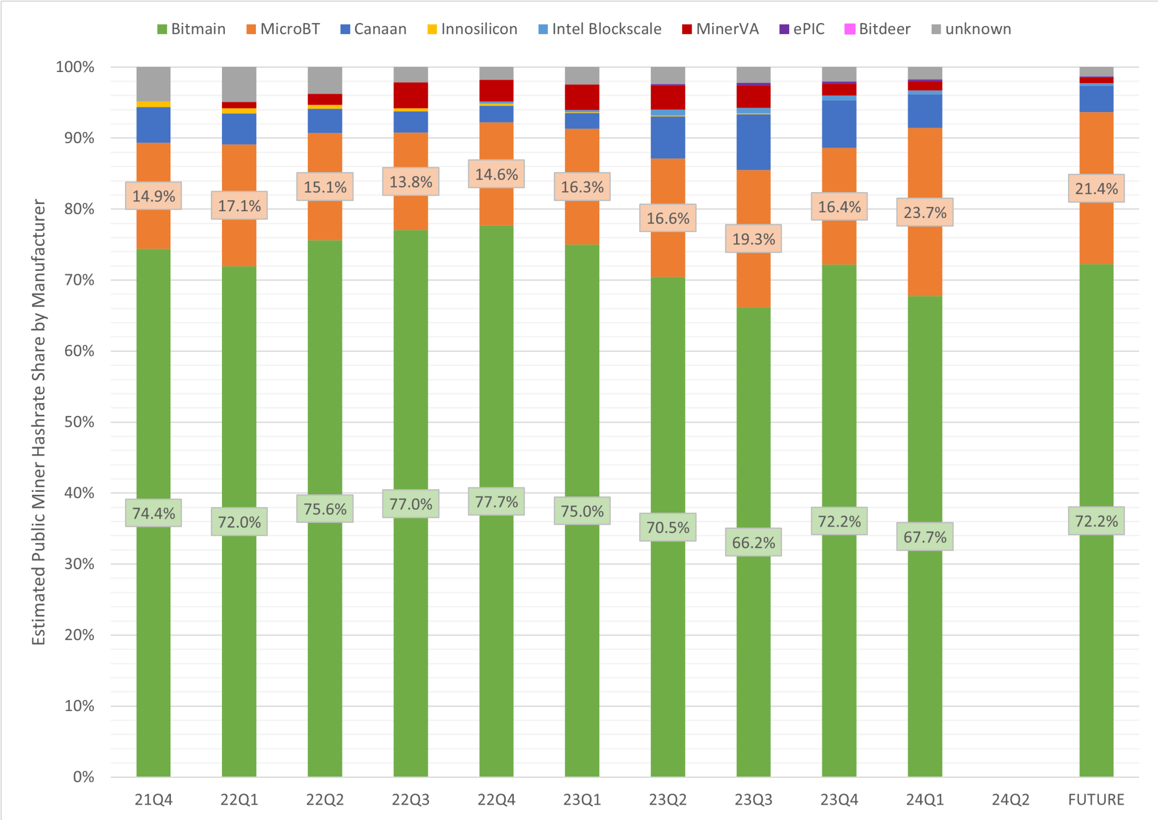
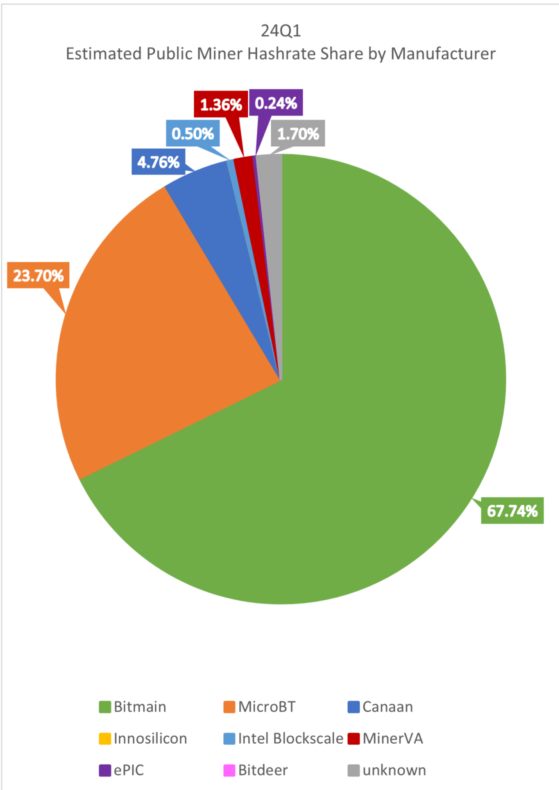
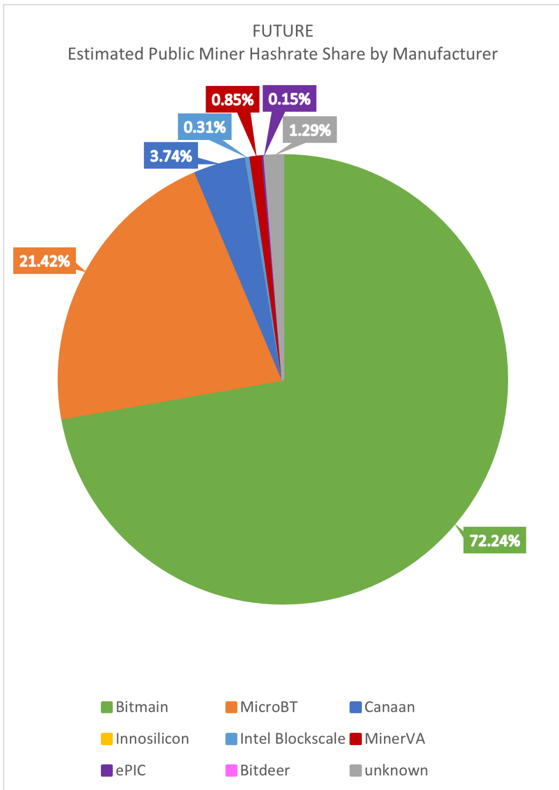


Figure 4.12: Dominance by Manufacturer



(a) First Quarter of 2024



(b) Future Outlook

Figure 4.13: Outlook on Share by Manufacturer

4.3.2 Share per Model

To find out the shares per each ASIC hardware model we present figure 4.9 in another way, see figure 4.14. This stacked chart is again sorted by the release date of the models from bottom to top, whereas the *unknown (gray)* hardware units are at the bottom and the *unknown (colored)*, but by manufacturer assignable hardware units are placed below models of the same manufacturer *(same color)*. Five Bitmain Antminer models have large shares of the public Bitcoin miner hashrate. These are the Antminer *S19*, *S19 Pro*, *S19j*, *S19j Pro*, and *S19 XP*. They chronologically, and according to their efficiency, pass along the leading position, as discussed in subsection 4.2.2. One MicroBT Whatsminer model also has a large share, that is the Whatsminer *M30S*. The overall trend is clear. Older, less efficient hardware models lose their share in hashrate and are taken offline, due to low profitability. This can be spotted on the bottom. As an example, we look closer at the Antminer S19 which was released in May 2020 and took a significant drop in hashrate share by 23Q4. That means public Bitcoin mining companies have been mining with this model for about three and a half years before selling them and most likely replacing them with the newer S19 XP and S19j XP. This seems probable since these start to gain hashrate share around the same time and all three of these models have the same form-factor[4]. So the trend is also that newer, more efficient hardware models drive out older rigs. Overall, a diversification is taking place, with more new hardware models coming online, then older ones going offline. To verify this, let us look at the estimated percentages.
In figure 4.15 we plot the same graphic and mark all hardware models that reached at least two consecutive quarters a share of over 5%. Between 21Q4 and 24Q1, these are the same five Bitmain Antminer models and the one MicroBT Whatsminer. The diversification shows up as only three models fulfilled the 5% threshold at the beginning of our analysis, and later up to six models. If we calculate an average share per deployed hardware model, we get a constantly decreasing percentage from 3.1% in 21Q4 to 0.8% in 24Q1. This figure additionally shows the expected outlook shares for 24Q4. Newer ASIC hardware models such as the Bitmain Antminer *S21*, *T21*, and the MicroBT Whatsminer *M66S* are expected to have larger portions of the public miner hashrate. MicroBT's strongest miner, the *M30s*, reached a share of 9.3% three and a half years after its release date. The S19 had 31.3% 19 months after its release date. The S19j Pro had 29%, the S19 XP had 26.7%, 18 months and 17 months after their release date respectively. The S21 is expected to have only a share of 22.8% 15 months after its release date. Especially the past numbers show the manufacturers' arms race to produce more efficient hardware and bring it to market as soon as possible. Additionally, the Bitcoin miners are competing to bring them online as fast as possible. The same figure with a 2% consecutive threshold, because also *Canaan* and *MinerVA* temporarily got noticeable shares in hashrate, is in the appendix C.3.2.
We also get more detail for future changes by comparing figure 4.16 with figure 4.17. It shows percentages of not dominant but still profitable mining hardware models. More importantly, we see that the dominant hardware models change but the overall picture remains the same with the duopoly of Bitmain Antminers and MicroBT Whatsminer.

[4]Bitmain Antminer Specifications: `https://support.bitmain.com/hc/en-us` [21.07.2024]

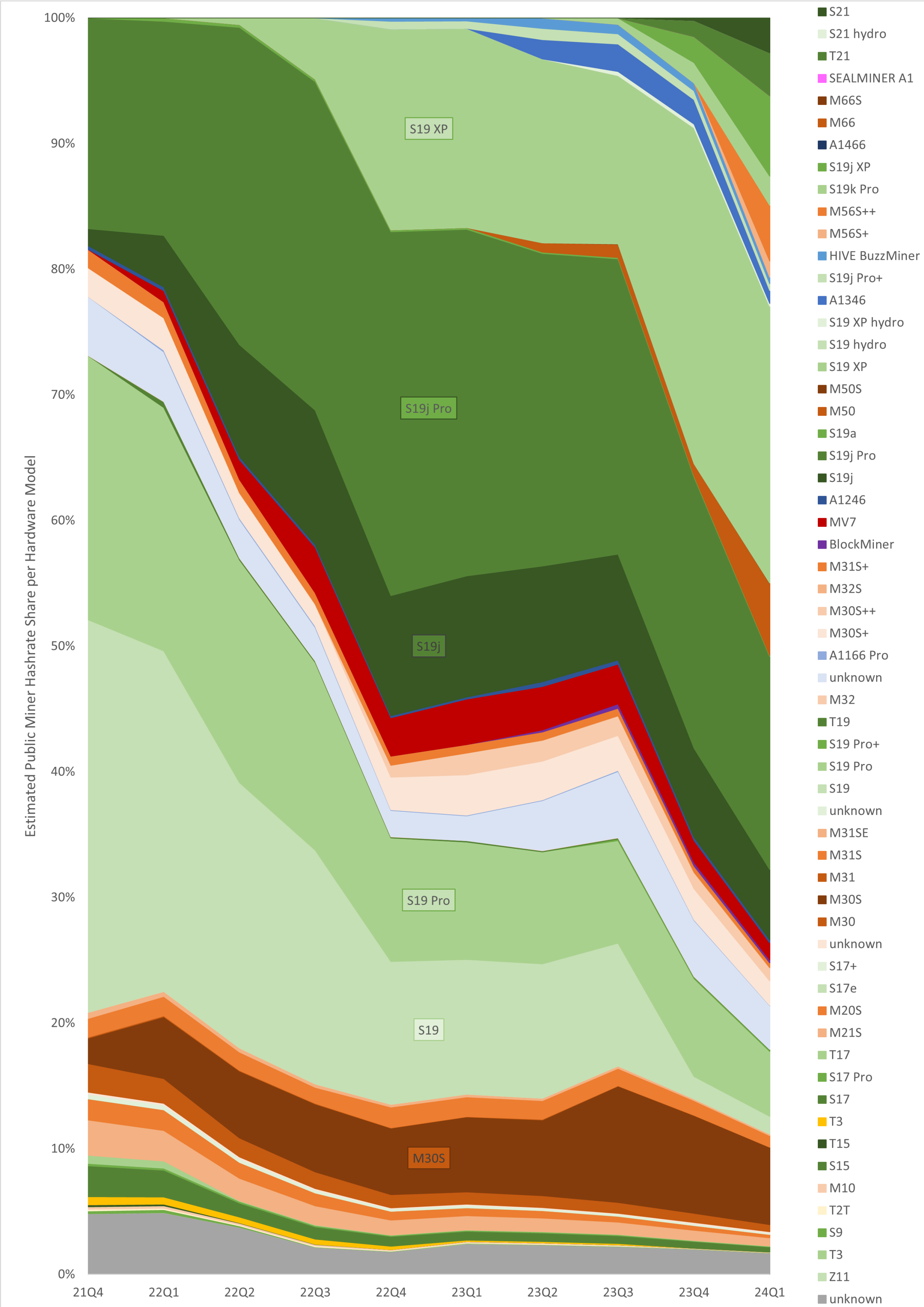


Figure 4.14: Hashrate Share per Hardware Model

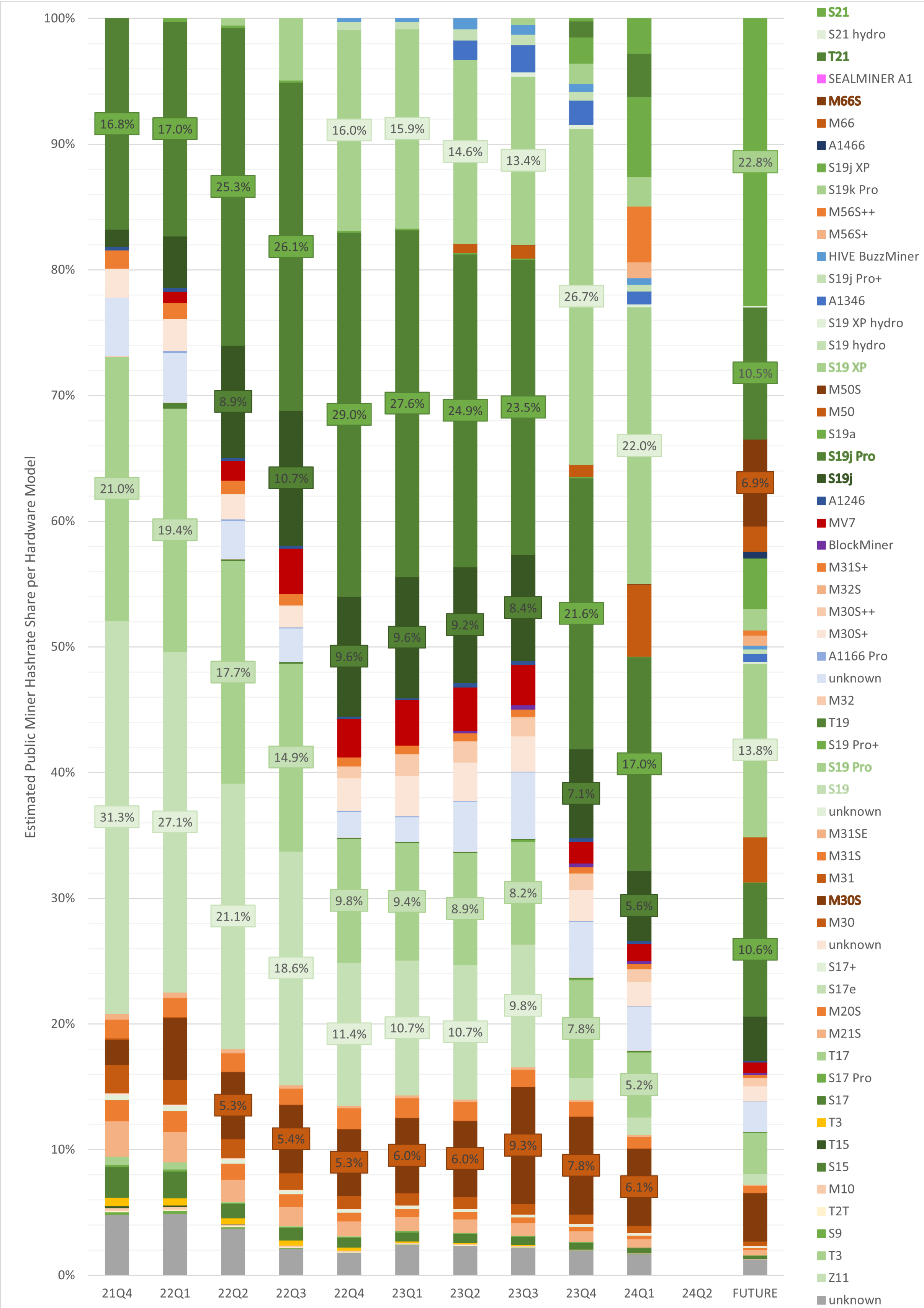


Figure 4.15: Dominance per Hardware Model

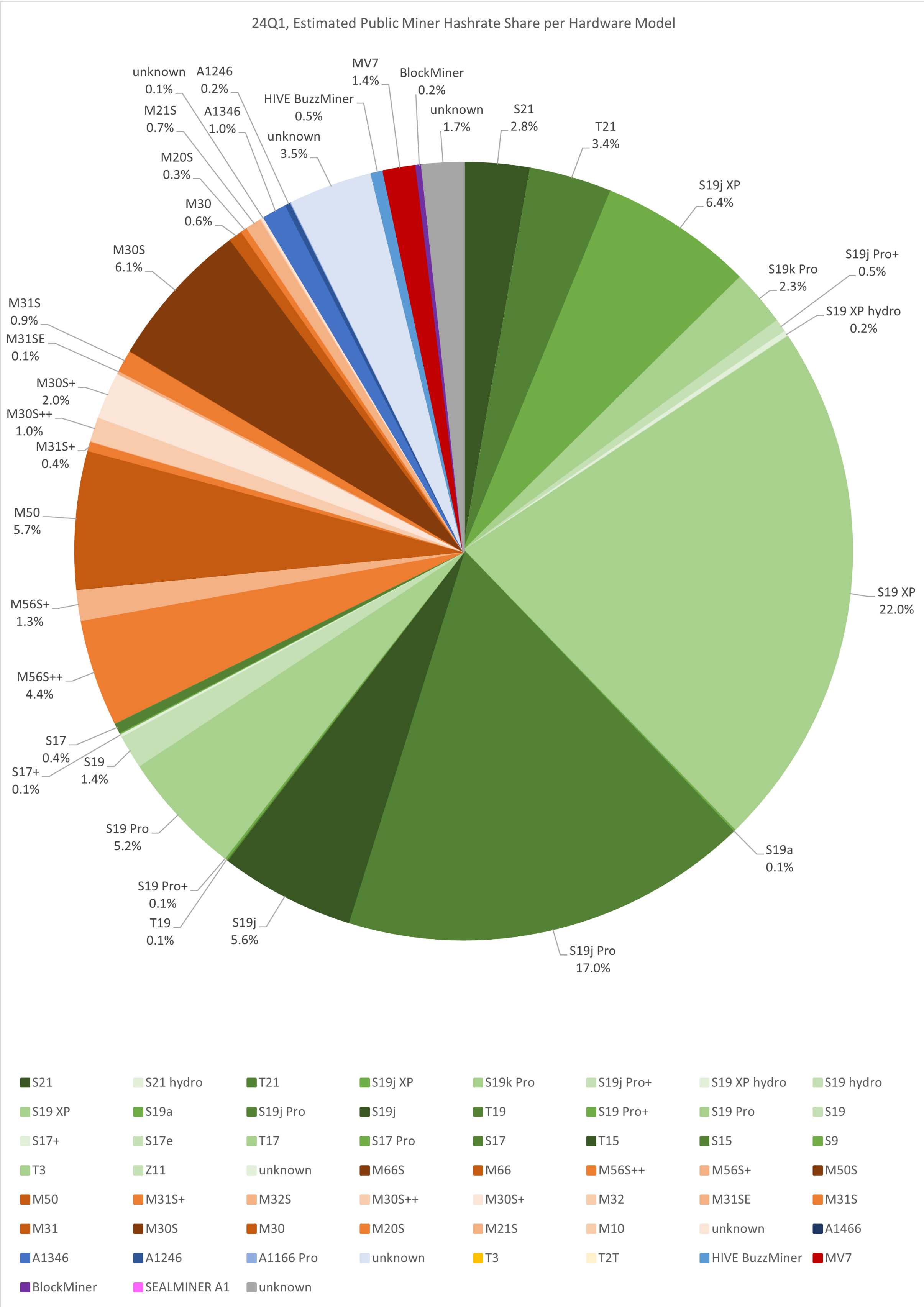


Figure 4.16: First Quarter of 2024 Hashrate Share per Model

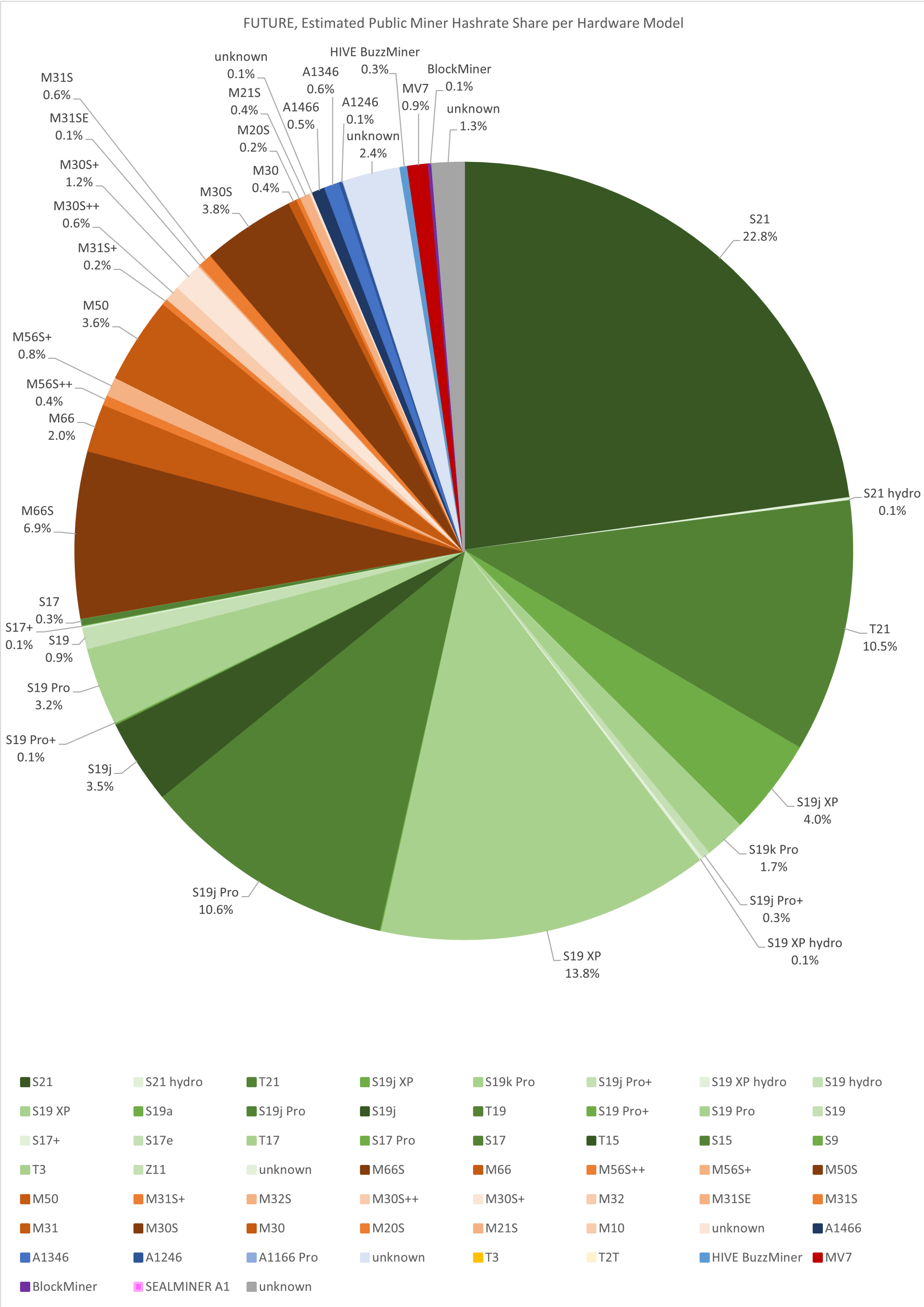


Figure 4.17: Outlook on Hashrate Share per Model

4.4 ASIC Hardware Efficiencies

Now we show the results following from the energy calculations described in 3.3. For every hardware model, we get a rough estimate of power demand. These calculations however presuppose multiple assumptions for the number of mining rigs and their operation, which we could collect from public reports and press releases. Here is a list of assumptions. It is complete to our knowledge but does not have to be exhaustive.
Assumptions already made for previous calculations:

- all additional mining rigs are deployed at the end of each quarter
- all mining rigs operate at the nominal hashrate
- unknown mining rig models operate at that quarter's average hashrate per manufacturer
- unknown mining rigs operate at that quarter's overall average hashrate
- no mining rigs are being overclocked or underclocked

Additional assumptions needed for power demand and electricity consumption estimations:

- all mining rigs operate at nominal efficiency
- unknown mining rig models operate at that quarter's average efficiency per manufacturer
- unknown mining rigs operate at that quarter's overall average efficiency
- all mining rigs operate with 100% up-time
- only the mining rig power demand is considered

Let us analyze our estimated average efficiency. It is itself part of the assumption list and looks like this, see figure 4.18. Efficiency increases over the period from 21Q4 to 24Q1 in two steps from 35.3 J/TH to 32 J/TH, and then to 28 J/TH . In other words, the energy required per TH/s or in general per computation dropped by 20% over two and one-quarter years. It is expected to drop by an additional 13.6% in the future, reaching an efficiency of 24.2 J/TH around the end of 2024. This does not consider recently announced and expected-to-be-released ASIC Bitcoin mining models such as the Bitmain Antminers S21 Pro, S21 XP, S21 XP Hydro, S21 XP Immersion, or the Canaan Avalon A1566, and A1566I. This will all come with efficiencies from 12 to 18.5 J/TH. As a reference, the most efficient hardware model included is the Bitmain Antminer S21 Hydro with 16 J/TH. Only a handful of the others included in our estimation are below the 20 J/TH mark.

We compare our estimated average hardware unit efficiency to the efficiency calculated for the CBECI and the efficiency estimated by Coin Metrics. All three show a down-sloping trend over the analyzed period but some strong divergences are prevalent in quarters 21Q4 and 22Q1. Overall our estimated efficiency is the lowest. It remains below Coin Metrics' efficiency for the entire period and lands below CCAF's for every quarter except for 23Q3. That is 13.9%, with a standard deviation of ±13.0%, and 10.3%, with a standard deviation of ±7.0%, below CBECI and Coin Metrics respectively. More details on this comparison and a graph are in the appendix Bitcoin's Average Efficiency Comparison C.1.

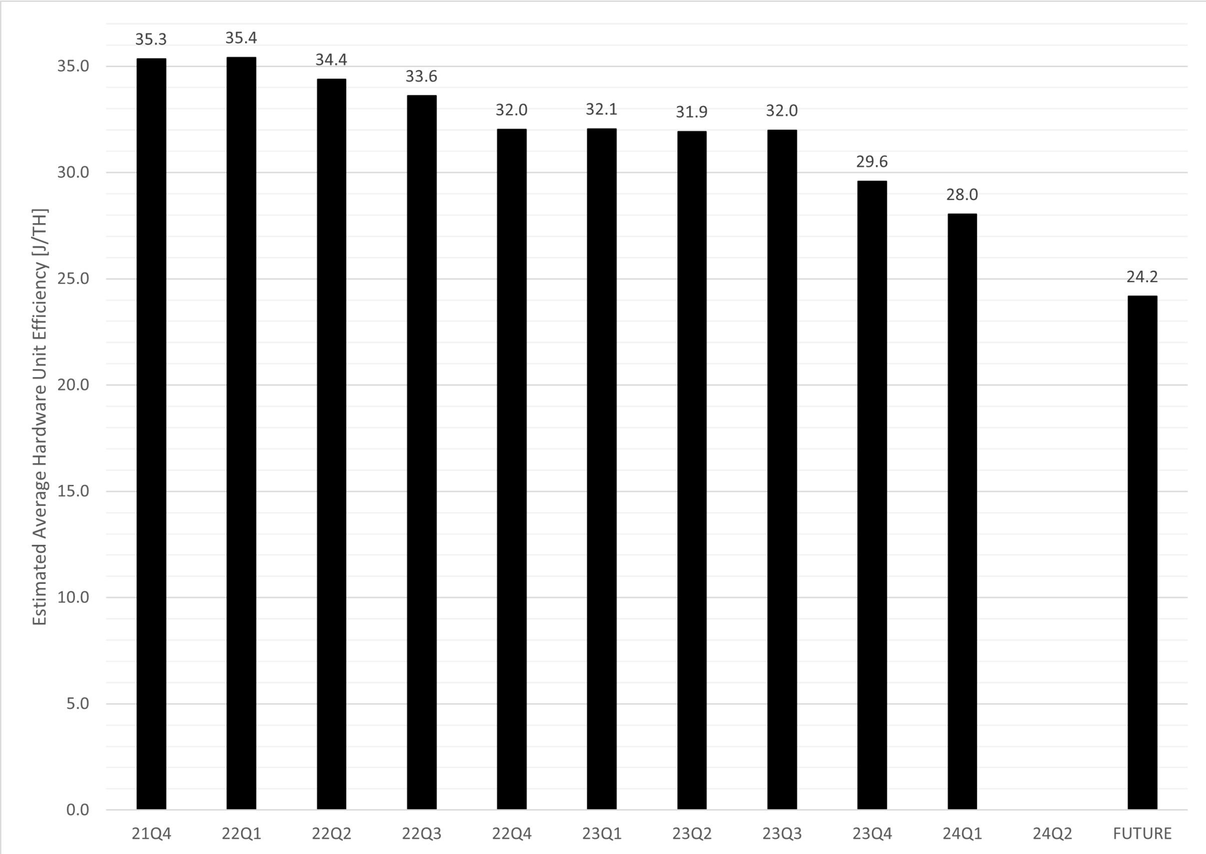


Figure 4.18: Average Installed Hardware Unit Efficiency

4.4.1 A Guesstimate of Bitcoin's Global Electricity Consumption

Having listed the assumptions on which the following estimations are based, let us look at power demand and energy consumption. Power demands for single hardware models are best represented in [MW] and reach values up to 671 MW in 24Q1. That is the Bitmain Antminer S19j Pro with 58 MW more than the S19 XP, which had the most hashrate in that quarter. So we see that hardware models with lower efficiencies need more power but are still kept online because they are still running profitably. Compared to hashrate growth, power demand growth only increased by about 13.64% per quarter, or 4.35% per month over the analyzed period. In Watts, the power demand of the 28 analyzed public companies grew from 1'149 MW in 21Q4 to 3'029 MW in 24Q1. Considering all assumptions, this can be converted to an estimated electricity consumption given in [TWh]. Multiplying by a constant factor for days in a year and hours in a day, we get a little over 10 TWh in 21Q4 and almost 32 TWh in 24Q1.

Doing the dubious but consistent extrapolation suggested in section 3.3 we get a guesstimate Bitcoin's global power demand and energy consumption. We use a PUE of 1.1 and end up with values for Bitcoin's global power demand going from 6.6 GW to 18.7 GW over these two years. Factoring time into these values, we get Bitcoin's annualized electricity consumption between 21Q4 and 24Q1 going from 57.4 TWh to 164.3 TWh. Since the hashrate share of the considered public mining companies is not constant over that period this inevitably also changes the rate of change in our extrapolated estimates. It comes in slightly lower, with an average growth of 12.39% per quarter or 3.97% per month. In fact, at a closer look, it is not as smooth growth as hashrate growth.

We used the same PUE as CBECI's "best-guess" PUE [1], which was also used in Coin Metrics' comparison [16]. Additionally, we compare our guestimate with Digiconomist's index. Compared to all three of them, similar deviations from a smooth exponential growth are captured. However, our extrapolated estimation gives us 14%, 14%, and 19% averaged lower demand and annualized consumption with a standard deviation of ±13%, ±10%, and ±32% compared to the CBECI, Coin Metrics, and Digiconomist's index respectively. Especially in the beginning period, our guesstimate is 38% below CBECI's, and 29% below Coin Metrics's power demand. These differences stem primarily from our lower average efficiencies, compared in figure C.1. That is exactly the result discussed in this section. Our estimated efficiency of 35.3 J/TH is much lower than CBECI's estimated average of 57.53 J/TH on December 31, 2021, and Coin Metrics' of 44.89 J/TH on January 2022. Still, our average estimated efficiency is well above CBECI's hypothetical minimum efficiency[5]. Digiconomist's estimated energy consumption is over three and a half times ours in 21Q4, before it drops following their estimated minimum[6] in 22Q4, which is more in line with the other estimates. Further details regarding this comparison are in the appendix Bitcoin's Electricity Consumption Comparison C.2.

Why did we call this subsection a guesstimate instead of an estimate? We notice that these energy calculations rely upon many assumptions and that the chosen PUE value affects the result significantly. During our data collection, we looked for public mining companies publishing PUE values. We found two of the 28 giving PUE values, even though this is not a required metric for transparent disclosure. Northern Data published already back in November 2020 that they developed an air-cooling system for their data center delivering a PUE of between 1.05 and 1.04[7]. Soluna Holdings published in November 2023 PUE values for their projects of 1.01 and 1.02[8]. These are much lower than CBECI estimated PUE and as a comparison, high-performance computing data centers can have a PUE of 1.036[9]. It makes sense to compare Bitcoin mining companies to such data centers since electricity costs are the main operational expense and a fierce global competition forces them to reduce overhead for lights, cooling, pumps, and so on as much as possible. Using such a PUE would reduce power demand by an additional 5%. This suggests that bottom-up data for PUE in Bitcoin mining is needed to reduce the error margins in such estimations. Additional correction terms, such as a reality-based up-time factor, should be researched and introduced to improve future results. A lower up-time of mining hardware would also reduce the electricity consumption estimate in our bottom-up approach.

[5] CBECI Energy efficiency of bitcoin mining hardware: `https://ccaf.io/cbnsi/cbeci` [21.07.2024]

[6] `https://digiconomist.net/bitcoin-energy-consumption` [21.07.2024]

[7] Press Release: `https://northerndata.de/en/investor-relations/news/northern-data-ag-commissions-first-data-center-in-the-netherlands` [21.07.2024]

[8] Q3 Results and Business Update: `https://www.solunacomputing.com/wp-content/uploads/2023/11/SLNH-Q3-23-Review-and-Business-Update.pdf` [21.07.2024]

[9] `https://www.nrel.gov/computational-science/measuring-efficiency-pue.html` [21.07.2024]

Chapter 5

Discussion

We looked at 28 public Bitcoin mining companies and gathered all the data on mining fleets and hardware models. Thus covering about one-fourth of Bitcoin's global hashrate, we found that hardware numbers are steadily increasing, coming mostly from the manufacturers Bitmain and MicroBT and that newer generation ASIC hardware models are produced in higher quantities. This is also reflected in the hashrate values we got. The public miners have a pretty constant and high share of self-mining and deploy hashrates from machines of a 90% duopoly of the two mentioned manufacturers. The dominant hardware model has been in its position for about 1.5 years before being overtaken in hashrate terms by a newer model. This arms race in Bitcoin mining makes manufacturers produce newer and more efficient hardware fast and miners trying to deploy these ASIC mining machines fast as well. The last dominant Antminer models have been shown to reach their peak dominance in a shorter time frame and with a lower percentage share of the total covered hashrate. This suggests that multiple hardware models are running simultaneously causing a more diversified mining feet. One miner has been deployed for at least 3.5 years. We suggest it has been replaced by newer generation models of the same manufacturer with the same form factor. The overall efficiency of the deployed hardware models also shows a clear trend toward more and more efficient models.

All of these results are in line with the expected trends known from the industry. We reinforce the experience-based knowledge by providing numbers of a representative share of the global hashrate. It clearly shows that Bitcoin mining is a fast-evolving and exponentially growing energy industry and that hardware models are updated at a fast pace.

We assumed the public miner hashrate to be representative of Bitcoin's global hashrate to extrapolate and compare our results with previous research. Our estimated global mining fleet efficiency landed below both CCAF's and Coin Metrics' estimations. The causes might be, that the CBECI uses BTC/USD price as input for their top-down calculations and that Coin Metrics' bottom-up approach does not capture models with a low hashrate share. Our guesstimated electricity consumption, using the same PUE as in the CCAF's research, also lands below the CBECI calculated electricity consumption, below the Coin Metrics estimated power demand, and below the energy consumption calculated by Digiconomist. This again might be caused by the same reasons or other unscientific rigor in their approaches. This implies that Bitcoin mining might run more efficiently than expected and commonly quoted, still providing the same computational power, meaning hashrate, to secure the network.

Our bottom-up approach used a replicable and extendible process, using real-world data and therefore needing fewer estimations. However its downside is, that it has a lower resolution giving only quarterly data points. For the same reason, it has a time lack between present time and data-availability. The approach also suffers from incomplete data availability in the beginning, which can only improve over time as more past data is known and tracked. This is to be encouraged, as our covered period did not look at an entire Bitcoin 4-year epoch or cycle.

Another point we found is, that it is difficult to track hardware models being taken offline, as public filings are mostly concerned with financial statements. For more precise estimations of total Bitcoin efficiency or electricity consumption further metrics are missing. To mention a few, a well-researched PUE, an up-time metric, and more information on over- and underclocked machines need to be gathered. Future research along these lines is of immense importance to understand Bitcoin mining better and to inform users, policymakers, critics, and proponents alike so that they can decide and act with data-backed research.

Chapter 6

Conclusion and Outlook

We followed the main idea to see if public Bitcoin mining filing documents give us more insights into the industry and Bitcoin mining in general. We could reinforce expert experiences, improve estimations, and collect a valuable database. We show growing trends in hardware units, hashrates, and increasing efficiencies. We found there to be a duopoly in Bitcoin mining hardware manufacturers, with most units coming from Bitmain and next from MicroBT. Our research gives a new way to look at the hardware model numbers, hashrates, and their shares. That way deployment of new hardware can be tracked, substitutions of hardware models can be estimated, and better extrapolations for estimated total efficiency and power demand or electricity consumption can be made. The explicit structuring of the data enables more information to be extracted, such as self-mining rates or average efficiencies. As with any approach looking into a decentralized system like Bitcoin, also this one has some limitations, mostly in data availability and granularity. Either way, additional approaches are welcome and help to deep dive into Bitcoin mining's workings, essentially bringing us closer to an understanding of the great impact Bitcoin could bring to our lives and to human civilization.

We recommend continuing with this approach in the future, collecting all publicly available data, and structuring it in a good way without losing detail. More interested parties can look at, improve, and work with such a database if it is made open-source. We encourage future analysis to cover at least one entire Bitcoin cycle and also would like to see more research on important real-world values for PUE, up-time, and over- and under-clocking rates. Future research would provide a basis showing Bitcoin mining as an essential growing energy industry that might reach levels of unimaginable importance. In the long-term, the direct linkage between (electrical) energy and value could turn out to give us the first constant in economics improving human economic calculation and resource distribution or at least driving energy prices in a global market closer together reducing one source of disparity in living standards. Bitcoin mining is the heartbeat of the Bitcoin network and backs the global money with never-before-seen characteristics.

Appendix A

Student Project Proposal

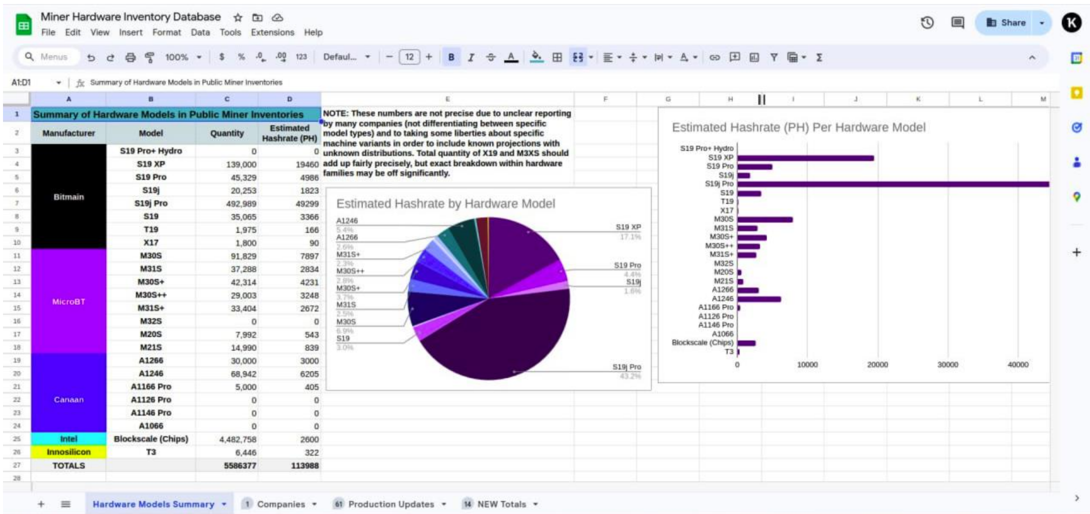
Samuel Wieland, D-ITET

Student Project Proposal

Type:	Semester Project
Titel:	**Distribution of ASIC Hardware Models of Public Bitcoin Miners over time**
Student:	Samuel Wieland (sawielan@student.ethz.ch)
Supervisors:	Dr. Sven Hildebrand (s.hildebrandt@crypto-risk-metrics.com)
Supervising Professor:	Prof. Dr. Florian Dörfler
Semester:	Spring Semester 2024
Earliest start date:	20.04.2024

Project description

In this project, we will investigate the historical development and deployment of hardware models by public Bitcoin Mining companies. Public companies represent a vast portion of Bitcoins total computational power (hashrate) and their data is publicly obtainable, which together represents a good approximation of reality. The resulting estimate hardware model distribution over time might give us insights into the future developments of this fast-evolving energy industry.



Summary of Hardware Models in Public Miner Inventories

Manufacturer	Model	Quantity	Estimated Hashrate (PH)
Bitmain	S19 Pro+ Hydro	0	0
	S19 XP	139,000	19460
	S19 Pro	45,329	4986
	S19j	20,253	1823
	S19j Pro	492,989	49299
	S19	35,065	3366
	T19	1,975	166
	X17	1,800	90
MicroBT	M30S	91,829	7897
	M31S	37,288	2834
	M30S+	42,314	4231
	M30S++	29,003	3248
	M31S+	33,404	2672
	M32S	0	0
	M20S	7,992	543
	M21S	14,990	839
Canaan	A1266	30,000	3000
	A1246	68,942	6205
	A1166 Pro	5,000	405
	A1126 Pro	0	0
	A1146 Pro	0	0
	A1066	0	0
Intel	Blockscale (Chips)	4,482,758	2600
Innosilicon	T3	6,446	322
TOTALS		5586377	113988

NOTE: These numbers are not precise due to unclear reporting by many companies (not differentiating between specific model types) and to taking some liberties about specific machine variants in order to include known projections with unknown distributions. Total quantity of X19 and M3XS should add up fairly precisely, but exact breakdown within hardware families may be off significantly.

Figure 1: Miner Hardware Inventory Database [1]

Motivation

The Markets in Crypto Assets Regulation (MiCA) was introduced in June 2023. The European Securities and Markets Authority (ESMA) is developing technical standards and guidelines for MiCA. In public consultations, ESMA aims to collect views, comments, and opinions from stakeholders and market participants on the appropriate implementation of MiCA [2].

Our research will give more insights into the mining industry, which might support the decision making for the MiCA regulation and be useful for stakeholders and market participants.

Approach

By building upon previous research done by Braiins, we will show historical developments of hardware mining models found in the companies' quarterly reports. We will identify all public traded miners, analyse their public reports, and extract all data describing their deployed Application Specific Integrated Circuit (ASIC) fleet or future deliveries of such hardware. This will give us estimates on hashrate by hardware model, market share by hardware manufacturers and by the public traded miners.

Goals

1. Learn about ASIC hardware models deployed in the field and get an understanding of the workings in the mining industry.
2. Gain insights into publicly traded miners and their reporting.
3. Extract insights from the found data set. Are trends visible? How is the industry evolving?
4. Build a custom data feed.

Tasks

1. Exchange ideas and collect previous research done by Braiins.
2. Extract all publicly available data from public miners' publications.
3. Visualize and analyse the found data set. Build a data feed which can be updated with future publications.
4. Summarize the results and write a final report.
5. Hold a presentation of this semester project at ETH Zurich.

References

[1] P. Connolly, *Miner Hardware Inventory Database,* 2024.

[2] European Securities and Markets Authority, "ESMA - Markets in Crypto-Assets Regulation (MiCA)," 20 4 2024. [Online]. Available: https://www.esma.europa.eu/esmas-activities/digital-finance-and-innovation/markets-crypto-assets-regulation-mica.

Appendix B

Database

B.1 Companies

Company			Hashrate [EH/s]													
NAME	TICKER	TYPE	21Q4	22Q1	22Q2	22Q3	22Q4	23Q1	23Q2	23Q3	23Q4	24Q1	24Q2	FUTURE	SOURCE	NOTES
Aker ASA	AKER															*no current mentioning of mining, as of June 202*
Argo Blockchain PLC	ARBK	*electrified*	-	-	-	-	-	-	-	-	2.4	-		-	https://argoblockchain.com/investors/financial-information/	
Argo Blockchain PLC	ARBK	*installed*	1.605	-	2.2	-	2.5	2.50	2.6	2.80	2.8	2.7		2.8	https://arg	[...]later this year, which is expected to increase
Ault Allinace Inc. (BitNile)	AULT	*reported*	-	-	-	-	2.25	-	-	-	2.1	-		-	https://ir.ault.com/reports-financials/sec-filings/	
Bit Digital Inc.	BTBT	*electrified*	-	-	1.06	1.35	-	1.25	1.78	1.19	2.5	2.76		-	https://bitdigital.wpengine.com/investors/financial-informat	
Bit Digital Inc.	BTBT	*installed*	1.6	1.6	2.7	2.7	2.6	2.6	3.4	3.7	3.9	4.2		6	https://bitdigital.wpengine.com/investors/financial-informat	
BIT Mining Ltd.	BTCM															*small miner (PH/s), as of June 2024*
Bitdeer Technologies Group	BTDR	*self-mining*	-	-	-	-	4.1	5.7	6.2	8.7	8.4	8.4		11.8	https://ir.bi	On March 26, 2024, the Company announced a h
Bitdeer Technologies Group	BTDR	*total*	8.1	-	-	-	14	18.3	18.8	21.2	21	22.5		-	https://ir.bi	*total includes hosted-mining*
Bitfarms Ltd.	BITF	*reported*	2.24	2.73	3.6	4.2	4.5	4.8	5.3	6.1	6.5	7		21	https://inve	Executing towards targets of 12 EH/s and 25 w/
BitFrontier Capital Holdings Inc.	BFCH															*no current mentioning of mining, as of June 202*
BitFuFu Inc.	FUFU	*self-mining*	-	-	4.28	-	4.5	-	14.90	-	22.4	-		-	https://ir.bi	*self-mining included leased hashrate*
BitFuFu Inc.	FUFU	*total*	3	-	6.3	-	11.1	18.8	15.2	-	22.9	28.6		-	https://ir.bitfufu.com/sec-filings/	
BlockQuarry Corp.	BLQC															*no current SEC filings, as of June 2024*
Bots Inc.	BTZI															*no current SEC filings, as of June 2024*
Canaan Inc.	CAN	*electrified*	-	-	-	-	-	-	-	0.8	1.89	3		-	https://investor.canaan-creative.com/financials/sec-filings,	
Canaan Inc.	CAN	*installed*	-	-	-	-	-	3.8	-	-	-	4		-	https://inve	Company decided to temporarily shut down appr
Cathedra Bitcoin Inc.	CBIT		0.177	0.207	0.217	0.203	0.343	0.343	0.387	0.355	0.403	0.38		4.8	https://cath	[...]bitcoin mining and hosting business with an
Cipher Mining Inc.	CIFR	*self-mining*	-	-	-	0.64	0.96	5.2	6.8	7.2	7.4	7.7		9.3	https://inve	We plan to deploy an additional[...]capacity by t
Cipher Mining Inc.	CIFR	*total*	-	-	-	1.3	1.95	6.1	7.8	8.2	8.4	8.7		11.6	https://inve	*total includes hosted-mining*
CleanSpark Inc.	CLSK	*reported*	2	2.4	2.8	5.75	6.2	6.7	6.7	9.6	10	16.4		20	https://inve	As of April 30, 2024, we operated a high of 17.3
Coin Citadel	CCTL															*small miner (PH/s), as of June 2024*
Core Scientific Inc.	CORZ	*self-mining*	6.7	8.3	10.3	13	15.7	16.1	15.1	15	16.9	19.3		-	https://investors.corescientific.com/investors/financials/sec	
Core Scientific Inc.	CORZ	*total*	13.7	16.2	17.9	22.5	23.7	21.8	22.3	22.3	23.2	25.5		-	https://inve	*total includes hosted-mining*
CryptoStar Corp.	CSTR															*no current SEC filings, as of June 2024*
Digihost Technology Inc.	DGHI	*reported*	0.415	0.75	0.65	0.65	0.65	0.9	1	1	1	2		6	https://ww	online
DMG Blockchain Solutions Inc.	DMGI	*reported*	0.42	0.595	0.625	0.65	0.715	0.88	0.71	0.75	0.96	1		2	https://dmgblockchain.com/news-events/, https://dmgblock	
Ebang International Holdings Inc.	EBON															*manufacturer, gives no further details on self-mi*
Galaxy Digital Holdings Ltd.	GLXY	*self-mining*	0.5	0.5	1	-	1	1	1.7	1.8	1.9	3.1		-	https://inve	*total includes hosted-mining*
Galaxy Digital Holdings Ltd.	GLXY	*total*	1.5	1.5	3	-	3	3	3.7	3.9	4.1	5.7		6	https://inve	[...]remain on track to achieve 6 EH/s of HUM in
GMO internet group Inc.	9449.T															manufacturer, gives no further detail on self-mir
Greenidge Generation Holdings Inc	GREE	*self-mining*	-	-	-	-	-	-	1.2	1.2	1.2	1.2		-	https://ir.greenidge.com/financials/quarterly-results	
Greenidge Generation Holdings Inc	GREE	*total*	1.4	1.6	2.5	2.4	2.4	2.5	4.1	4.6	3	4.6		-	https://ir.gr	*total includes hosted-mining*
Griid Infrastructure Inc.	GRDI															*infrastructure developer, gives no further detail*
Gryphon Digital Mining Inc.	GRYP	*reported*	-	-	-	-	-	-	-	-	0.864	0.912		-	https://ir.gr	Daniel Batten 1 EH/s
HIVE Digital Technologies Ltd.	HIVE	*reported*	-	-	-	-	2	3.2	3.5	3.8	4	5		6	https://hivedigitaltechnologies.com/investors/reporting, htt	
Hut 8 Corp.	HUT	*self-mining*	-	-	-	2.2	-	-	-	3.1	6.3	7.3		-	https://hut8	*total includes hosted-mining*
Hut 8 Corp.	HUT	*total*	-	-	-	2.6	7.3	7.3	7.3	3.9	8	15.9		63	https://hut8	[...]hosted approximately 68,200 miners (about 7
iMining Technologies Inc.	IMIN															*no current mentioning of mining, as of June 202*
Integrated Ventures Inc.	INTV															*gives no further detail on self-mining, as of June*
Investview Inc.	INVU															*small miner (PH/s), as of June 2024*
Iris Energy Ltd.	IREN	*reported*	-	-	4.3	-	4.7	-	5.6	5.6	5.6	10		30	https://www.globenewswire.com/news-release/2024/05/15	
Marathon Digital Holdings Inc.	MARA	*electrified*	-	-	0.7	-	-	11.5	17.7	19.1	24.7	-		-	https://ir.mara.com/sec-filings/all-sec-filings/content/0001	
Marathon Digital Holdings Inc.	MARA	*installed*	3.5	3.9	3.6	3.8	7	15.4	21.8	23.1	25.2	27.8		50	https://ir.mara.com/sec-filings/all-sec-filings/content/0001	
Mawson Infrastructure Group Inc.	MIGI	*self-mining*	0.9	1.35	1.7	0.5	0.2	-	-	-	-	-		-	https://www.mawsoninc.com/sec-filings/	
Mawson Infrastructure Group Inc.	MIGI	*total*	-	-	1.8	2.1	-	1.8	-	-	-	-		10	https://ww	*total includes hosted-mining*
MGT Capital Investments Inc.	MGTI															*small miner (PH/s), as of June 2024*
Northern Data AG	NB2	*reported*	-	3.95	4.34	4	3.6	3.8	3.77	3.75	3.34	3.2		9	https://northerndata.de/en/investor-relations/publications	
Phoenix Group Holdings Plc.	PHX															*distributor of WhatsMiner, gives no further detai*
Riot Platforms Inc.	RIOT	*reported*	3.1	4.3	4.4	5.6	9.7	10.5	10.7	10.9	12.4	12.4		31.5	https://ww	Riot anticipates achieving a total self-mining ha
SATO Technologies Corp.	SATO	*reported*	-	-	-	-	-	0.54	0.54	0.54	0.54	0.54		1	https://ww	Daniel Batten 0.54
SBI Holdings Inc.	8473.T															*no current mentioning of mining, as of June 202*
Singularity Future Technology Ltd.	SGLY															*no current mentioning of mining, as of June 202*
Soluna Holdings Inc.	SLNH	*electrified*	-	-	0.0174	-	-	-	-	-	-	-		-	https://ww	Daniel Batten 0.92
Soluna Holdings Inc.	SLNH	*installed*	0.429	0.666	0.9826	0.875	-	-	0.9	-	2.6	2.5		-	https://ww	Daniel Batten 0.92

SOS Ltd.	SOS															*gives no further detail on self-mining, as of June 2*
Sphere 3D Corp.	ANY	*reported*	0.1	0.1	0.1	0.5	0.37	0.446	1	1.3	1.3	1.3		-	https://sphere3d.gcs-web.com/financials/quarterly-results	
Strategic Asset Leasing Inc.	LEAS															*no current mentioning of mining, as of June 2024*
Stronghold Digital Mining Inc.	SDIG	*electrified*	-	0.9	-	-	-	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/financial-information/	
Stronghold Digital Mining Inc.	SDIG	*installed*	1.9	2.4	3	1.6	2.6	2.8	2.8	3.5	4.1	4.4		7	https://ir.strongholddigitalmining.com/financial-information/	
Terawulf Inc.	WULF	*electrified*	-	-	-	-	-	-	-	5	5	-		-	https://investors.terawulf.com/sec-filings/all-sec-filings http	
Terawulf Inc.	WULF	*installed*	-	-	2.8	-	-	-	5.5	5.5	5.5	8		13.3	https://inve	avg, installed; mid-2024, [...]will bring TeraWulf's
Winland Holdings Corp.	WELX															*small miner (PH/s), as of June 2024 (detail on dis*
XTRA Bitcoin Inc.	CBTC															*small miner (PH/s), as of June 2024 (detail on dis*

B.2 Hardware

Company		Hardware																
NAME	TICKER	MANUFACTURER	MODEL	21Q4	22Q1	22Q2	22Q3	22Q4	23Q1	23Q2	23Q3	23Q4	24Q1	24Q2	FUTURE	SOURCE	NOTES
Aker ASA	AKER																
Argo Blockchain PLC	ARBK	Bitmain	T17	-	-	-4792	-	-	-	-	-	-	-		-	https://ass	[...]removed 460 PH/s of non-operationa
Argo Blockchain PLC	ARBK	Bitmain	S17	-	-	-4792	-	-	-	-	-	-	-		-	https://ass	[...]removed 460 PH/s of non-operationa
Argo Blockchain PLC	ARBK	Bitmain	S19	-	-	-	-	-23619	-	-	-	-	-		-	https://ass	[...] new-in-box Bitmain S19J Pro machin
Argo Blockchain PLC	ARBK	Bitmain	Z11	-	-	-	-	-	-	-	-	-	-		-	https://ass	Our mining hardware primarily consists o
Argo Blockchain PLC	ARBK	Bitmain	S19 Pro	-	-	-	-	-	-	-	-	-	-		-	https://ass	[...]lease costs related to the S19 and S1
Argo Blockchain PLC	ARBK	Bitmain	S19j Pro	-	-	30000	-	32994	-	23600	-	23619	-		-	https://ass	[...]two-year hosting services agreement
Argo Blockchain PLC	ARBK	ePIC	BlockMiner	-	-	-	-	-	-	1242	2750	-	-		-	https://ass	During the third quarter of 2023, the Con
Argo Blockchain PLC	ARBK	TOTAL	total	24000	-	-	-	31000	-	27000	-	33750	-		-	https://assets-global.website-files.com/6192808c2	
Ault Allinace Inc. (BitNile)	AULT	Bitmain	S19 Pro	4000	-	-	-2000	-	-	-	-	3549	-		-	https://ir.a	[...]Agreement dated July 23, 2021, Bitm
Ault Allinace Inc. (BitNile)	AULT	Bitmain	S19j	754	4000	8000	12000	-	-	-	-	-	-		-	https://ir.a	[...]12,000 S19j miners[...], of which 754
Ault Allinace Inc. (BitNile)	AULT	Bitmain	S19j Pro	1885	-	-	6500	16017	-	5075	-	11050	-		-	https://ir.a	[...]16,000 S19j Pro Antminers[...]As of D
Ault Allinace Inc. (BitNile)	AULT	Bitmain	S19 XP	-	-	-	-	4628	-	664	-	4628	-		-	https://ir.ault.com/reports-financials/sec-filings/?s	
Ault Allinace Inc. (BitNile)	AULT	Bitmain	S19 XP hydro	-	-	-	-	-	-	-	1140	-	-		-	https://ir.a	[...]1,140 S19 XP Hydro Antminers anticip
Ault Allinace Inc. (BitNile)	AULT	unknown	unknown	-	-	-	-6572	-	-	-	-	-	-		-	https://ir.a	At the time of Compute North's bankrup
Ault Allinace Inc. (BitNile)	AULT	TOTAL	total	-	-	-	-	-	12000	21871	21871	-	-		-	https://ir.ault.com/reports-financials/sec-filings/?s	
Bit Digital Inc.	BTBT	Bitmain	S17	3641	3641	3641	3641	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	S17e	50.5	-	-	-	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	S17 Pro	1259	-	-	-	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	S17+	931	-	-	-	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	T3	769	769	769	769	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	T17	451	-	-	-	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	T17+	44	544	544	544	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	S19	-	-	-	-	-	-	3600	3600	3600	-		-		
Bit Digital Inc.	BTBT	Bitmain	S19 Pro	605	605	12005	12005	-	-	-	-	-	2350		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	Bitmain	S19 Pro+	-	-	-	-	-	-	-	1100	1100	-		-		
Bit Digital Inc.	BTBT	Bitmain	S19j Pro	-	-	-	-	-	-	-	900	-	-		-	https://www.sec.gov/Archives/edgar/data/171035	
Bit Digital Inc.	BTBT	Bitmain	S19j Pro+	-	-	-	-	-	-	2200	2200	2200	-		-		
Bit Digital Inc.	BTBT	Bitmain	S19k Pro	-	-	-	-	-	-	-	3600	4000	-		1150	https://www.sec.gov/Archives/edgar/data/171035	
Bit Digital Inc.	BTBT	MicroBT	M21S	16296	16196	15293	15190	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	MicroBT	M20S	3690	3690	3681	3681	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	MicroBT	M10	1938	1938	1938	1938	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	MicroBT	M30S	261	261	261	261	-	-	-	-	-	-		-	https://www.sec.gov/ix?doc=/Archives/edgar/data/	
Bit Digital Inc.	BTBT	MicroBT	M50S	-	-	3	3	-	-	-	-	-	-		-		
Bit Digital Inc.	BTBT	TOTAL	total	27744	27644	38135	38032	37676	37676	44886	46852	46548	48898		-	https://ww	Bitcoin miners only
BIT Mining Ltd.	BTCM																
Bitdeer Technologies Group	BTDR	Bitdeer	SEALMINER A1	-	-	-	-	-	-	-	-	-	-		-	https://ir.bitdeer.com/news-releases/news-release-	
Bitdeer Technologies Group	BTDR	Bitmain	unknown	-	-	-	-	-	-	-	-	-	-		-	https://ww	probably Antminer, as mentioned
Bitdeer Technologies Group	BTDR	MicroBT	unknown	-	-	-	-	-	-	-	-	-	-		-	https://ww	probably Whatsminer, as mentioned
Bitdeer Technologies Group	BTDR	Canaan	unknown	-	-	-	-	-	-	-	-	-	-		-	https://ww	probably Avalon Miner, as mentioned
Bitdeer Technologies Group	BTDR	TOTAL	self	-	-	-	-	-	67000	70000	92000	86000	86000		-	https://ir.bitdeer.com/financials/quarterly-results	
Bitdeer Technologies Group	BTDR	TOTAL	total	-	-	-	-	-	196000	199000	221000	215000	226000		-	https://ir.bitdeer.com/financials/quarterly-results	

Bitfarms Ltd.	BITF	MicroBT	M20S	4311	4311	4311	3471	2512	2212	1972	1132	731	473		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	MicroBT	M30S	2062	13685	21936	27162	30210	33036	36018	36018	36018	36018		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	MicroBT	M31S	6391	6742	6391	6391	12653	12653	12653	12653	12517	12517		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	MicroBT	M31S+	5911	5911	6262	6262	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	MicroBT	M50	-	-	-	-	-	-	-	1927	2473	2572		-	https://investor.bitfarms.com/news-events/press-re	
Bitfarms Ltd.	BITF	Bitmain	S9	6060	6060	2154	-	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Bitmain	S15	368	368	101	59	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Bitmain	T15	1645	1645	442	378	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Bitmain	S19j	700	-	-	-	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Bitmain	S19j Pro	7172	7172	7172	7172	7172	7172	10052	16461	16361	16061		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Bitmain	T21	-	-	-	-	-	-	-	-	-	2982		19280	https://investor.bitfarms.com/news-events/press-re	
Bitfarms Ltd.	BITF	Bitmain	S21	-	-	-	-	-	-	-	-	-	-		3888	https://investor.bitfarms.com/news-events/press-re	
Bitfarms Ltd.	BITF	Bitmain	S21 hydro	-	-	-	-	-	-	-	-	-	-		740	https://investor.bitfarms.com/news-events/press-re	
Bitfarms Ltd.	BITF	Innosilicon	T3	5082	5082	5082	5082	4439	1848	1848	1848	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Innosilicon	T2T	1364	1364	1364	1364	1272	1272	1272	1272	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	Canaan	A10	1024	1024	144	144	-	-	-	-	-	-		-	https://investor.bitfarms.com/sec-filings/annual-rep	
Bitfarms Ltd.	BITF	TOTAL	total	41390	53364	55359	57485	58258	58193	63815	71311	67068	70623		88000	https://investor.bitfarms.com/sec-filings/annual-rep	
BitFrontier Capital Holdings Inc.	BFCH																
BitFuFu Inc.	FUFU	Bitmain	S17	-	-	-	-	-1	-	-	-	-	-		-	https://s3.a	While BitFuFu primarily relied on Antmine
BitFuFu Inc.	FUFU	Bitmain	S19	-	-	-	-	-	-	-	-	-	-		-	https://s3.a	While BitFuFu primarily relied on Antmine
BitFuFu Inc.	FUFU	Bitmain	S19j	3000	-	-	-	-	-	-	-	-	-		-	https://s3.a	[...]fromAntminer S19 series, more than 8
BitFuFu Inc.	FUFU	Bitmain	S19j Pro	-	-	-	-	-	-	-	-	-	-		-	https://s3.a	BitFuFu has been leasing more advanced
BitFuFu Inc.	FUFU	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	-		-	https://s3.a	As of December 31, 2023, all of the miner
BitFuFu Inc.	FUFU	TOTAL	self	-	-	-	-	-	-	126400	-	-	-		-		self-owned and leased miners
BitFuFu Inc.	FUFU	TOTAL	total	33000	-	65500	-	-	-	131000	-	-	-		-		includes customers' hosted miners
BlockQuarry Corp.	BLQC																
Bots Inc.	BTZI																
Canaan Inc.	CAN	Canaan	unknown	-	-	-	-	-	-	13000	26000	-	-		-	https://inve	[...]the partner's failure to install 13,000 u
Canaan Inc.	CAN	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-		
Cathedra Bitcoin Inc.	CBIT	Bitmain	S9	-1185	-195	-	-	-	-	-	-	-	-		-	https://cat	Cathedra purchased 1,400 Bitmain Antmi
Cathedra Bitcoin Inc.	CBIT	Bitmain	S19j Pro	-	323	1125	894	1991	-	4164	3164	4164	4164		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	Bitmain	S19 XP	-	-	-	-	200	-	200	200	200	200		-	https://cat	On July 11, 2022, the Company announce
Cathedra Bitcoin Inc.	CBIT	MicroBT	M30S	180	-	-	-	-	-	-	-	-	-		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	MicroBT	M31S	-	-	1980	-	-	-	90	150	150	-		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	MicroBT	M31SE	1980	-	-	-	-	-	-	-	-	-		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	MicroBT	M32	180	-	-	-	-	-	-	-	-	-		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	MicroBT	M32S	-	-	180	-	-	-	90	150	150	-		-	https://cathedra.com/_resources/financials/MDA_2	
Cathedra Bitcoin Inc.	CBIT	TOTAL	total	-	-	-	-	4041	4041	4544	4664	4664	4364		-	https://cathedra.com/investors/financial-reports/	
Cipher Mining Inc.	CIFR	Bitmain	S19j Pro	-	970	-	12953	7574	12196	14907	14907	14907	-		-	https://investors.ciphermining.com/static-files/9443	
Cipher Mining Inc.	CIFR	Bitmain	S21	-	-	-	-	-	-	-	-	-	-		-		
Cipher Mining Inc.	CIFR	Bitmain	T21	-	-	-	-	-	-	-	-	-	-		37396	https://inve	[...]we entered into a Future Sales and Pu
Cipher Mining Inc.	CIFR	MicroBT	M30S	-	-	-	-	5944.3	11642	11706	11706	11706	-		-	https://investors.ciphermining.com/static-files/9443	
Cipher Mining Inc.	CIFR	MicroBT	M30S+	-	-	-	-	5944.3	11642	11706	11706	11706	-		-	https://investors.ciphermining.com/static-files/9443	
Cipher Mining Inc.	CIFR	MicroBT	M30S++	-	-	-	-	5944.3	11642	11706	11706	11706	-		-	https://investors.ciphermining.com/static-files/9443	
Cipher Mining Inc.	CIFR	Canaan	A1346	-	-	-	-	-	-	11000	11000	11000	-		-		
Cipher Mining Inc.	CIFR	Canaan	A1466	-	-	-	-	-	-	-	-	-	-		8350	https://inve	[...]agreements with Canaan to purchase
Cipher Mining Inc.	CIFR	TOTAL	total	-	970	-	12953	25407	-	61024	61024	61025	-		-	https://inve	As of March 31, 2023, the Company had c

CleanSpark Inc.	CLSK	Bitmain	S19	-	-	-	1799.9	-	-	-	-	-	-		-	https://d18	On August 17, 2022,[...], the Company co
CleanSpark Inc.	CLSK	Bitmain	S19 Pro	-	-	-	-	-	-	-	-	-	-		-	https://d18	Most miners[...]are by Bitmain[...], incluc
CleanSpark Inc.	CLSK	Bitmain	S19j Pro	-	3336	-	4980.2	-	-	-	-	-	-		-	https://d18	The borrowings[...]are collateralized by :
CleanSpark Inc.	CLSK	Bitmain	S19j Pro+	-	-	-	-	-	-	-	-	-	-		-	https://d18	We currently utilize several types of ASIC
CleanSpark Inc.	CLSK	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	-		-	https://d18	"
CleanSpark Inc.	CLSK	Bitmain	S21	-	-	-	-	-	-	-	-	-	-		-	https://d18	"
CleanSpark Inc.	CLSK	Bitmain	S21	-	-	-	-	-	-	-	-	-	-		160000	https://inv	[...]we have now fully funded the remaini
CleanSpark Inc.	CLSK	MicroBT	M30S	-	-	-	-	-	-	-	-	-	-		-	https://d18	"
CleanSpark Inc.	CLSK	TOTAL	deployed	18000	-	-	42000	63700	-	68000	88000	88500	-		-		
CleanSpark Inc.	CLSK	TOTAL	total	22900	-	-	58500	67972	-	91000	113500	146000	-		-		
Coin Citadel	CCTL																
Core Scientific Inc.	CORZ	Bitmain	S19	-	-	-	-	-	-	-	-	-	-		-	https://cor	Acquire 112,800 additional S19, S19 Pro,
Core Scientific Inc.	CORZ	Bitmain	S19j	-	-	-	-	-	-	-	-	-	-		-	https://cor	Self-mining[...]deployment of approxima
Core Scientific Inc.	CORZ	Bitmain	S19 Pro	-	-	-	-	-	-	-	-	-	-		-	https://cor	Develop its sixth mining[...]facility in[...]N
Core Scientific Inc.	CORZ	Bitmain	S19j Pro	-	-	-	-	-	-	-	-	-	-		-	https://cor	"
Core Scientific Inc.	CORZ	Bitmain	S19j XP	-	-	-	-	-	-	-	-	14200	28400		-	https://d18	Acquisition of Antminer S19J XP miners w
Core Scientific Inc.	CORZ	Bitmain	S21	-	-	-	-	-	-	-	-	-	6450		12900	https://d18	Acquisition of Antminer S21 miners with a
Core Scientific Inc.	CORZ	TOTAL	self	66800	8200	103000	130000	153000	155000	144900	144300	158000	172000		-	https://inv	self-miners
Core Scientific Inc.	CORZ	TOTAL	total	140700	164000	232000	232000	234000	207000	210900	206200	209100	223900		-	https://inv	total miners
CryptoStar Corp.	CSTR																
Digihost Technology Inc.	DGHI	Bitmain	S17+	700	-	-	-	-	-	-	-	-	-		-	https://ww	[...]acquisition of 700 Bitmain S17+ 76TH
Digihost Technology Inc.	DGHI	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	4640		-	https://ww	Digihost will received an upfront deposit
Digihost Technology Inc.	DGHI	MicroBT	M30	6032	-	-	-	-	-	-	-	-	-		-	https://ww	[...]Digihost will have added approximate
Digihost Technology Inc.	DGHI	unknown	unknown	9900	-	-	-	-	-	-	-	-	-		-	https://ww	[...]purchase agreement to acquire appro
Digihost Technology Inc.	DGHI	TOTAL	deployed	-	-	-	7000	10000	-	-	-	-	-		-	https://www.sedarplus.ca/csa-party/viewInstance/	
Digihost Technology Inc.	DGHI	TOTAL	total	12000	12000	12000	12000	-	-	-	-	-	-		-	https://www.sedarplus.ca/csa-party/viewInstance/	
DMG Blockchain Solutions Inc.	DMGI	Bitmain	S19	9500	-313	-	-	-	-	-	-	-	-		-	https://ww	DMG purchases 1,800 New Generation B
DMG Blockchain Solutions Inc.	DMGI	Bitmain	S19 XP	-	-	1800	1500	-	350	-	-	-	-		-	https://ww	DMG has purchased from Bitmain a total
DMG Blockchain Solutions Inc.	DMGI	Bitmain	S19 Pro	2000	-	-	-	-	350	-	-	-	-		-	https://ww	DMG Adds New Hosting Client with 2,000
DMG Blockchain Solutions Inc.	DMGI	Bitmain	S19j Pro	441	-	450	7850	-	850	-	-	-	-		-	https://ww	Miners Added: 441 S19J Pros 21 Annual R
DMG Blockchain Solutions Inc.	DMGI	Bitmain	T21	-	-	-	-	-	-	-	-	-	4550		-	https://dmgblockchain.com/news-events/, https://d	
DMG Blockchain Solutions Inc.	DMGI	unknown	unknown	1350	2636	1336	1052	1350	1286	1336	1852	-	-		-	https://dmgblockchain.com/news-events/, https://d	
DMG Blockchain Solutions Inc.	DMGI	TOTAL	total	-	-	7272	8025	8933	9282	9581	9921	9921	9921		-	https://dmgblockchain.com/news-events/, https://d	
Ebang International Holdings Inc.	EBON																
Galaxy Digital Holdings Ltd.	GLXY	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-	https://investor.galaxy.com/financials/quarterly-res	
GMO internet group Inc.	9449.T																
Greenidge Generation Holdings Inc.	GREE	Bitmain	S17	6600	-	-	-	-	-	-	-	-	-		-	https://ir.g	December 31, 2021, we had approximate
Greenidge Generation Holdings Inc.	GREE	Bitmain	T17	50	-	-	-	-	-	-	-	-	-		-	https://ir.g	December 31, 2021, we had approximate
Greenidge Generation Holdings Inc.	GREE	Bitmain	S19	3850	-	-	-	-	-	-	-	-	4000		-	https://ir.g	December 31, 2021, we had approximate
Greenidge Generation Holdings Inc.	GREE	Bitmain	S19 Pro	3850	-	-	-	-	-	-	-	-	2000		-	https://ir.g	The miners associated with Greenidge's c
Greenidge Generation Holdings Inc.	GREE	Bitmain	S19j Pro	-	2100	8100	-	-	1500	-	-	-	900		-	https://ir.g	The miners associated with Greenidge's c
Greenidge Generation Holdings Inc.	GREE	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	3600		-	https://ir.g	The miners associated with Greenidge's c
Greenidge Generation Holdings Inc.	GREE	Bitmain	S19 hydro	-	-	-	-	-	-	-	-	-	200		-	https://ir.g	The miners associated with Greenidge's c
Greenidge Generation Holdings Inc.	GREE	MicroBT	M30	2500	-	-	-	-	-	-	-	-	-		-	https://ir.g	December 31, 2021, we had approximate
Greenidge Generation Holdings Inc.	GREE	MicroBT	M31	430	-	-	-	-	-	-	-	-	-		-	https://ir.g	December 31, 2021, we had approximate
Greenidge Generation Holdings Inc.	GREE	TOTAL	self	17300	19400	27500	24500	24200	17050	10200	10200	10700	1200		-	https://ir.greenidge.com/financials/quarterly-results	
Greenidge Generation Holdings Inc.	GREE	TOTAL	total	17300	19400	27500	24500	24200	24700	38700	42300	28800	42300		-	https://ir.g	On March 15, 2023, we entered into a ho
Griid Infrastructure Inc.	GRDI																
Gryphon Digital Mining Inc.	GRYP	Bitmain	S21	-	-	-	-	-	-	-	-	-	-		-	https://ir.g	Machine upgrade program completed wi
Gryphon Digital Mining Inc.	GRYP	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-	https://www.gryphondigitalmining.com/	

HIVE Digital Technologies Ltd.	HIVE	Bitmain	S19j Pro	-	-	-	-	-	-	1169	-	-	-		-	https://www.newsfilecorp.com/release/165844/HI\	
HIVE Digital Technologies Ltd.	HIVE	Bitmain	S19j Pro+	-	-	-	-	3570	-	3600	-	-	-		-	https://hivedigitaltechnologies.com/news/hive-bloc	
HIVE Digital Technologies Ltd.	HIVE	Bitmain	S19k Pro	-	-	-	-	-	-	-	-	-	9800		-	https://www.newsfilecorp.com/release/165844/HI\	
HIVE Digital Technologies Ltd.	HIVE	Bitmain	S19 XP	-	-	-	-	-	-	1100	-	-	-		-	https://www.newsfilecorp.com/release/165844/HI\	
HIVE Digital Technologies Ltd.	HIVE	Bitmain	S21	-	-	-	-	-	-	-	-	-	3500		7000	https://hivedigitaltechnologies.com/news/hive-digit	
HIVE Digital Technologies Ltd.	HIVE	MicroBT	M30S	-	-	-	-	-	-	-	-	-	-		-	https://hivedigitaltechnologies.com/news/hive-bloc	
HIVE Digital Technologies Ltd.	HIVE	MicroBT	M30S+	5292	-	-	-	-	-	-	-	-	-		-	https://hivedigitaltechnologies.com/news/hive-bloc	
HIVE Digital Technologies Ltd.	HIVE	MicroBT	M30S++	-	-	-	-	-	-	-	-	-	-		-	https://hivedigitaltechnologies.com/news/hive-bloc	
HIVE Digital Technologies Ltd.	HIVE	Canaan	unknown	16900	-	-	-	-	-	-	-	-	-		-	https://www.coindesk.com/business/2021/10/29/hi	
HIVE Digital Technologies Ltd.	HIVE	Intel Blockscale	HIVE BuzzMiner	-	-	-	-	1423	-	5000	-	-	-		-	https://hiv	[...]received and installed 1,423 of its HI\
HIVE Digital Technologies Ltd.	HIVE	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-		
Hut 8 Corp.	HUT	Bitmain	S19j Pro	-	-	-	-	-	-	-	-	18000	18000		-	https://cdn	As of December 31, 2023, the Company h
Hut 8 Corp.	HUT	TOTAL	self	-	-	-	-	-	-	30200	-	18000	18000		-	https://cdn	As of March 31, 2024, including our net s
Hut 8 Corp.	HUT	TOTAL	total	-	-	-	-	-	-	182000	-	68200	68200		-	https://cdn.kscope.io/3beab1321e79fdb01fbed0f36	
iMining Technologies Inc.	IMIN																
Integrated Ventures Inc.	INTV																
Investview Inc.	INVU																
Iris Energy Ltd.	IREN	Bitmain	S19j	-	-	18889	-	-	-	-	-	-	-		-	https://iris	[...]three binding hardware purchase agr
Iris Energy Ltd.	IREN	Bitmain	S19j Pro	-	-	19800	-	-	-	-	-	-	-		-	https://iris	[...]secured by 19,800 Bitmain S19j Pro n
Iris Energy Ltd.	IREN	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	-		-	https://iris	[...]assuming the purchase of Bitmain S1
Iris Energy Ltd.	IREN	Bitmain	S21	-	-	-	-	-	-	-	-	-	7002		51480	https://iris	[...]51,480 Bitmain S21 Pro[...]scheduled
Iris Energy Ltd.	IREN	Bitmain	T21	-	-	-	-	-	-	-	-	6842.1	15789		53263.16	https://the	[...]bought another 1.3 EH/s of Bitmain's
Iris Energy Ltd.	IREN	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-	https://iris	Our Bitcoin mining operations currently u
Marathon Digital Holdings Inc.	MARA	Bitmain	S9	-5900	-	-	-	-	-	-	-	-	-		-	https://ir.n	[...]January 14, 2021, the Company sold i
Marathon Digital Holdings Inc.	MARA	Bitmain	S19	70000	-	-	-	-	-	-	-	600	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	Bitmain	S19 Pro	20500	-	-	-	3805	-	-	-	2800	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	Bitmain	S19j Pro	40000	-	-	-	75500	-	-	-	64090	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	Bitmain	S19 XP	-	-	-	-	33600	-	-	-	133826	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	Bitmain	S19k Pro	-	-	-	-	-	-	-	-	7000	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	Bitmain	S21	-	-	-	-	-	-	-	-	1000	-		-	https://ir.mara.com/sec-filings/all-sec-filings/conter	
Marathon Digital Holdings Inc.	MARA	MicroBT	unknown	700	-	-	-	700	-	-	-	1300	-		-	https://ir.n	On July 29, 2020, the Company announce
Marathon Digital Holdings Inc.	MARA	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-	https://ir.n	March 31, 2024[...]approximately 226,00
Mawson Infrastructure Group Inc.	MIGI	Bitmain	S19 Pro	250	-	-	-	-	-	-	-	-	-		-	https://ww	[...]announces it has taken delivery of 25
Mawson Infrastructure Group Inc.	MIGI	Bitmain	S19 XP	-	-	-	-	-	-	-	-	15876	-		-	https://apr	[...]co-location services for approximate
Mawson Infrastructure Group Inc.	MIGI	Bitmain	S19j Pro	-	-	-	-	-	-	-	-	-	-		-	https://apr	Exahash capacity assumes installation of
Mawson Infrastructure Group Inc.	MIGI	MicroBT	M30	-	-	-	-	-	-	-	-	-	-		-	https://apr	Exahash capacity assumes installation of
Mawson Infrastructure Group Inc.	MIGI	MicroBT	M31	-	-	-	-	-	-	-	-	-	-		-	https://apr	Exahash capacity assumes installation of
Mawson Infrastructure Group Inc.	MIGI	Canaan	A1246	1158	-	-	-	-	-	-	-	-	-		-	https://ww	[...]announces it has taken delivery of 25
Mawson Infrastructure Group Inc.	MIGI	TOTAL	deployed	8792	20697	24419	26360	-	6104	-	-	-	-		-	https://www.mawsoninc.com/sec-filings/	
Mawson Infrastructure Group Inc.	MIGI	TOTAL	storage&transit	15010	7528	10910	6990	-	17228	-	-	-	-		-	https://www.mawsoninc.com/sec-filings/	
Mawson Infrastructure Group Inc.	MIGI	TOTAL	total	23802	39225	35329	33350	-	23332	-	-	-	-		-	https://www.mawsoninc.com/sec-filings/	
MGT Capital Investments Inc.	MGTI																
Northern Data AG	NB2	MicroBT	M50	-	-	-	-	-	-	-	-	-	61404		-	https://lp.r	Die jüngst erworbene MicroBT Flüssigküh
Northern Data AG	NB2	MicroBT	M30S	-	-	-	-	-	-	-	37356	-	-		-	https://lp.r	Hashrate: 3.25 EH/s. M30S-generation. 2
Northern Data AG	NB2	TOTAL	total	18000	43500	47300	42000	43829	40562	40508	40248	35639	-		-	https://lp.northerndata.de/hubfs/Investor%20Relati	
Phoenix Group Holdings Plc.	PHX																

Riot Platforms Inc.	RIOT	Bitmain	S19 Pro	30907	34608	-	-	-	-	-	-	-	-		-	https://s3.:	During 2021, we received 34,608 additior
Riot Platforms Inc.	RIOT	Bitmain	S19j	-	8311	15240	29504	38370	43500	-	-	-	-		-	https://s3.:	Additionally,[...]purchase orders with Bitr
Riot Platforms Inc.	RIOT	Bitmain	S19j Pro	-	-	-	-	9000	-	-	-	-	-		-	https://s3.:	"
Riot Platforms Inc.	RIOT	Bitmain	S19 XP	-	-	-	10053	30000	-	-	-	-	-		-	https://s3.:	"
Riot Platforms Inc.	RIOT	MicroBT	M56S+	-	-	-	-	-	-	-	-	-	8320		-	https://ww	Riot has secured an initial order of 33,28
Riot Platforms Inc.	RIOT	MicroBT	M56S++	-	-	-	-	-	-	-	-	-	24960		3724	https://ww	Under the purchase order, Riot will recei
Riot Platforms Inc.	RIOT	MicroBT	M66	-	-	-	-	-	-	-	-	-	-		14778	https://ww	"
Riot Platforms Inc.	RIOT	MicroBT	M66S	-	-	-	-	-	-	-	-	-	-		48058	https://ww	"
Riot Platforms Inc.	RIOT	TOTAL	total	30907	42919	44720	55728	88556	94176	95904	98694	112994	-		-	https://s3.:	[...]excludes 17,040 miners currently offli
SATO Technologies Corp.	SATO	unknown	unknown	-	-	-	-	-	5600	-	-	-	-		-	https://ww	[...]approximately 5,600 air-cooled comp
SATO Technologies Corp.	SATO	TOTAL	total	-	-	-	-	-	-	-	-	-	-		-		
SBI Holdings Inc.	8473.T																
Singularity Future Technology Ltd.	SGLY																
Soluna Holdings Inc.	SLNH	TOTAL	total	-	-	-	-	-	-	-	-	23655	24000		-	https://www.solunacomputing.com/investors/upda	
SOS Ltd.	SOS																
Sphere 3D Corp.	ANY	Bitmain	S19j Pro	1000	1000	1000	4026	11850	-	-	-	-3336	-		-	https://sphere3d.gcs-web.com/news-and-events/ne	
Sphere 3D Corp.	ANY	TOTAL	deployed	1000	1000	1000	1000	3665	4330	9995	12450	12800	12500		9100	https://sph	24 Apr Update
Sphere 3D Corp.	ANY	TOTAL	total	1000	1000	1000	5026	16876	-	-	-	-	-		-	https://sphere3d.gcs-web.com/news-and-events/ne	
Strategic Asset Leasing Inc.	LEAS																
Stronghold Digital Mining Inc.	SDIG	Bitmain	S9	-	2000	-	-	-	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/static-files/6	
Stronghold Digital Mining Inc.	SDIG	Bitmain	S17+	-	315	-	-	-	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/static-files/6	
Stronghold Digital Mining Inc.	SDIG	Bitmain	T19	-	2050	800	800	-	-	-	-	-	-		-	https://ir.s	[...]acquire 400 Antminer T19 miners wit
Stronghold Digital Mining Inc.	SDIG	Bitmain	S19a	-	1000	1000	1000	-	-	-	-	-	-		-	https://ir.s	As of March 31, 2022, all 1,000 Bitmain S
Stronghold Digital Mining Inc.	SDIG	Bitmain	S19j	400	1000	1600	1800	2400	-	-	-	-	-		-		
Stronghold Digital Mining Inc.	SDIG	Bitmain	S19j Pro	4000	-	4500	-4500	-	-	-	-	-	-		-	https://ir.s	Before selling these miners, the Company
Stronghold Digital Mining Inc.	SDIG	Bitmain	S19 XP	-	-	-	-	-	-	-	-	-	-		-	https://ir.s	[...]PA 1800 Bitmain Antminer S19 XP mir
Stronghold Digital Mining Inc.	SDIG	Bitmain	S19k Pro	-	-	-	-	-	-	-	-	2800	2800		-	https://ir.s	[...]PA 1800 Bitmain Antminer S19 XP mir
Stronghold Digital Mining Inc.	SDIG	MicroBT	M20S	-	1000	-	-	-	-	-	-	-	-		-		
Stronghold Digital Mining Inc.	SDIG	MicroBT	M30S	5140	7280	7280	7280	7090	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/static-files/d	
Stronghold Digital Mining Inc.	SDIG	MicroBT	M30S+	2140	4280	4280	4280	7090	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/static-files/d	
Stronghold Digital Mining Inc.	SDIG	MicroBT	M31S	-	770	770	770	-	-	-	-	-	-		-		
Stronghold Digital Mining Inc.	SDIG	MicroBT	M50	-	-	-	-	-	-	5000	6030	6030	1100		-	https://ir.s	We received and installed the M50 Mine
Stronghold Digital Mining Inc.	SDIG	MicroBT	M50S	-	-	-	-	-	-	-	105	105	-		-	https://ir.s	We received these miners during the thir
Stronghold Digital Mining Inc.	SDIG	unknown	unknown	-	1735	1735	1735	-	-	-	-	-	-		-	https://ir.s	These miners were received and recorde
Stronghold Digital Mining Inc.	SDIG	Canaan	A1166 Pro	-	649	-	-	-	-	-	-	-	-		-	https://ir.strongholddigitalmining.com/static-files/6	
Stronghold Digital Mining Inc.	SDIG	Canaan	A1246	-	151	-	-	-	-	2000	2000	2000	-		-	https://ir.strongholddigitalmining.com/static-files/6	
Stronghold Digital Mining Inc.	SDIG	Canaan	A1346	-	-	-	-	-	-	-	6000	7100	1100		-	https://ir.s	The miners were delivered and installed
Stronghold Digital Mining Inc.	SDIG	MinerVA	MV7	-	3200	7200	9100	10700	12700	12700	12700	12700	12700		-	https://ir.s	As of June 30, 2022, MinerVa has delivere
Stronghold Digital Mining Inc.	SDIG	TOTAL	self	20500	25900	26200	18200	25000	25000	30000	32000	30000	30000		-	https://ir.strongholddigitalmining.com/financial-info	
Stronghold Digital Mining Inc.	SDIG	TOTAL	total	20500	25900	32000	18200	29500	31000	38000	42000	44000	44000		-	https://ir.strongholddigitalmining.com/financial-info	
Terawulf Inc.	WULF	Bitmain	S19 Pro	-	-	-	-	5000	-	-	-	13000	13000		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	Bitmain	S19j Pro	-	2469	-	-	2700	5450	-	-	14200	14200		-	https://inv	[...]Company purchased2,469 of Nautilus
Terawulf Inc.	WULF	Bitmain	S19 XP	-	-	-	6000	9400	13000	-	-	6300	6300		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	Bitmain	S19j XP	-	-	-	-	-	-	-	-	-	26500		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	Bitmain	S19k Pro	-	-	-	-	-	-	-	-	-	1600		4600	https://inv	In early April, an additional 3,000 S19k Pr
Terawulf Inc.	WULF	MinerVA	MV7	-	-	-	10000	-	13200	-	-	4100	4100		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	MicroBT	M30S+	-	-	-	-	-	-	-	-	1200	1200		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	TOTAL	deployed	-	-	-	-	-	-	-	29000	44100	63000		-	https://investors.terawulf.com/sec-filings/all-sec-fil	
Terawulf Inc.	WULF	TOTAL	total	-	-	-	-	-	-	-	30000	45900	66900		-	https://inv	added Nautilus Cryptomine Facility Capa
Winland Holdings Corp.	WELX																
XTRA Bitcoin Inc.	CBTC																

Appendix C

Additional Results

C.1 Bitcoin's Average Efficiency Comparison

Our estimated average hardware model efficiency is the average of all deployed ASIC units by the analyzed 28 public Bitcoin mining companies. This was described in section 3.3. These values are then considered to be representative for Bitcoin's global installed average efficiency. Here compared with CBECI's calculated estimate and Coin Metrics derived estimate. Our approach does not have data for 24Q2 yet, but an expected future estimate of below 25 J/TH can be made for approximately 24Q4.

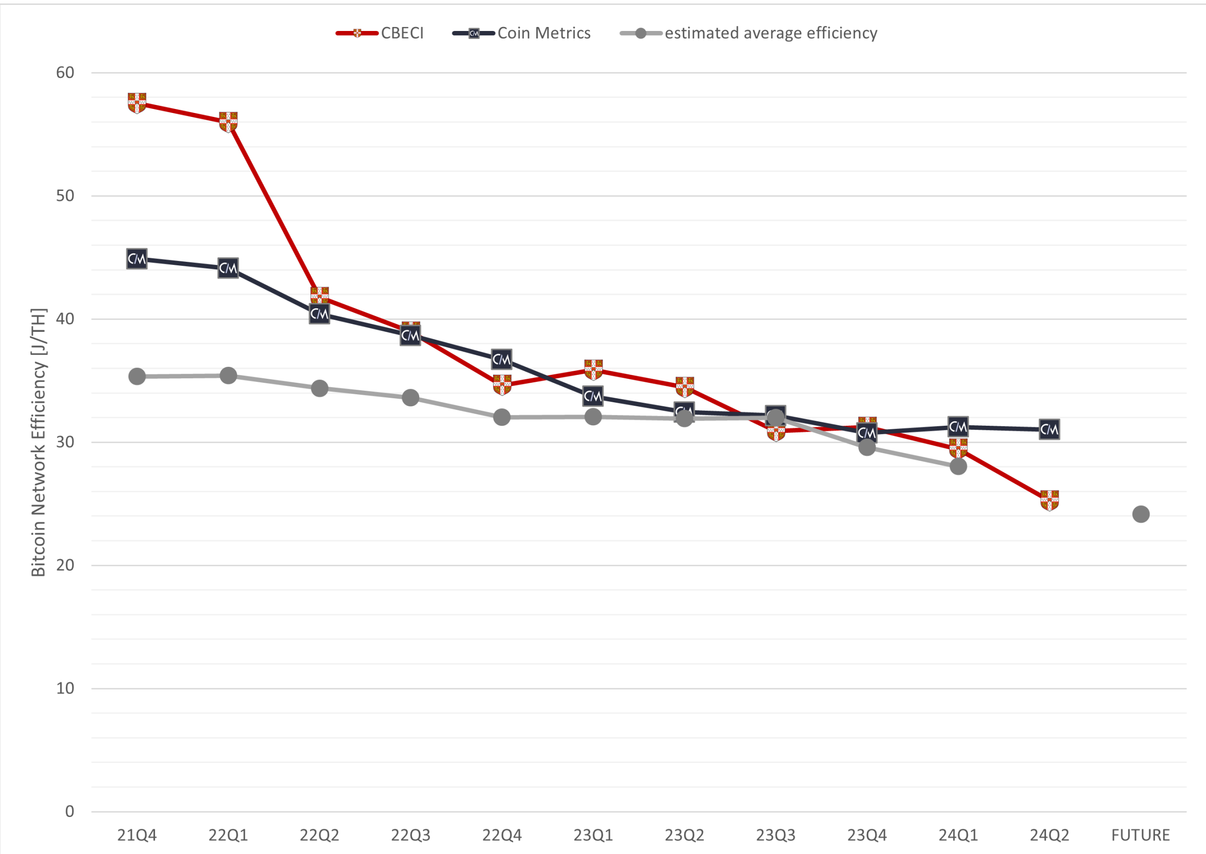


Figure C.1: Bitcoin's Average Efficiency Comparison

C.2 Bitcoin's Electricity Consumption Comparison

Our power demand guess is based on the energy values for each hardware model, calculated as described in section 3.3. These values are aggregated to estimate power demand for the 28 public mining companies. This is then extrapolated to Bitcoins global hashrate using the estimated percentages discussed in section 4.3 and a global PUE of 1.1. For the extrapolated energy consumption we use the same formula as used in the CBECI [1]:

$$E_{Bitcoin} = \frac{365.25 * 24h}{1000} * P_{Bitcoin} \text{ ; } [E_{Bitcoin}] = TWh, \text{ } [P_{Bitcoin}] = GW \tag{C.1}$$

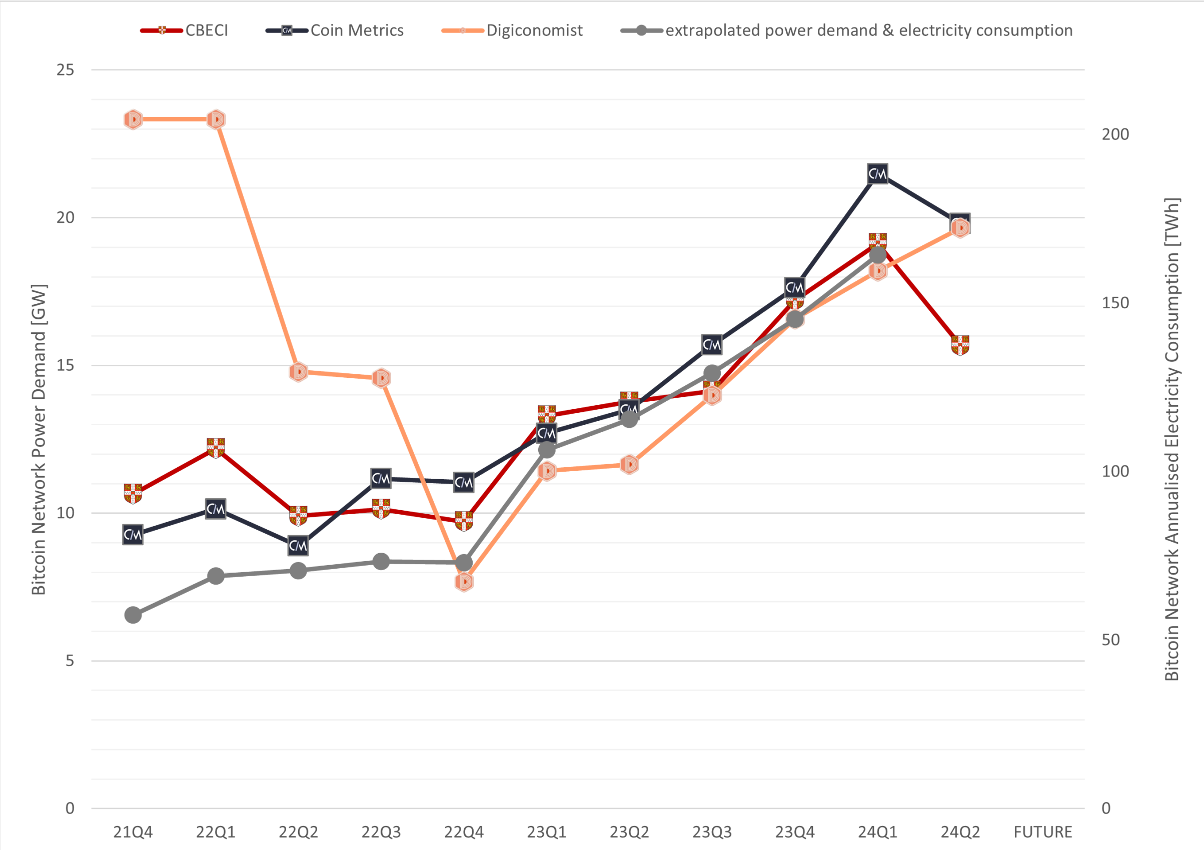


Figure C.2: Bitcoin's Power Demand and Annualized Energy Consumption Comparison

C.3 More Charts

C.3.1 ASIC Hardware Hashrates

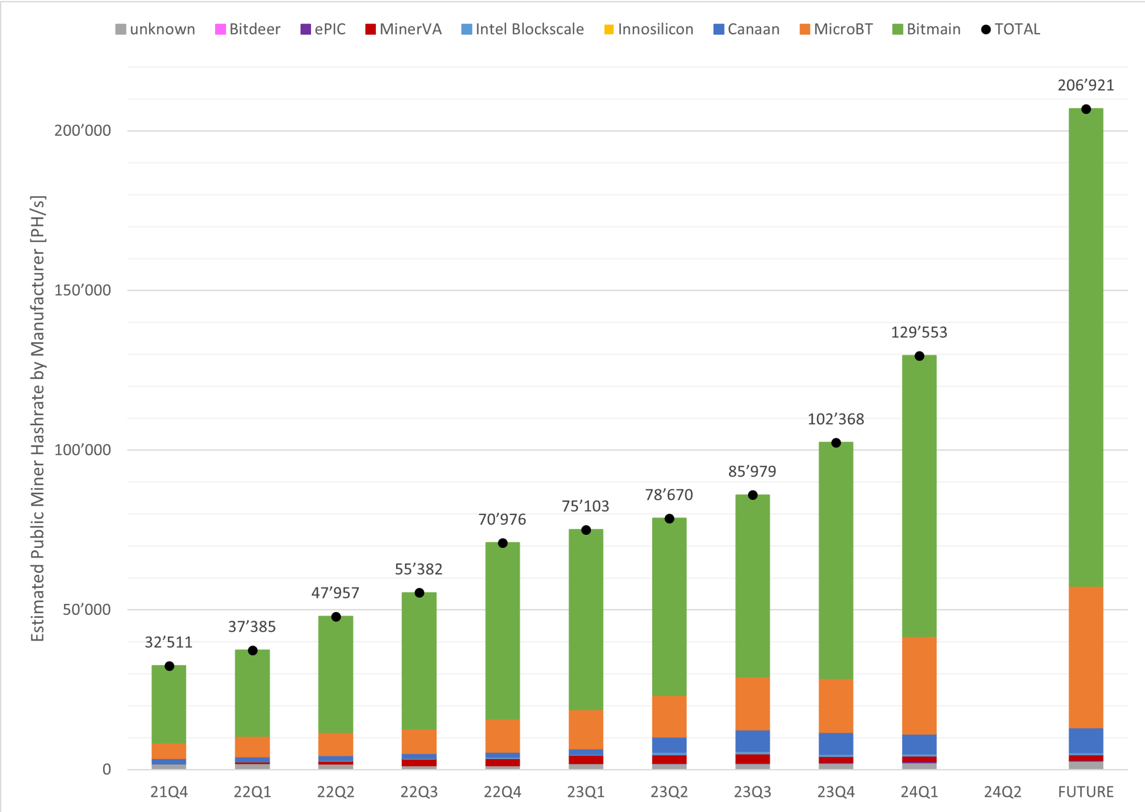


Figure C.3: Distribution of Hashrates by Manufacturer (inverted)

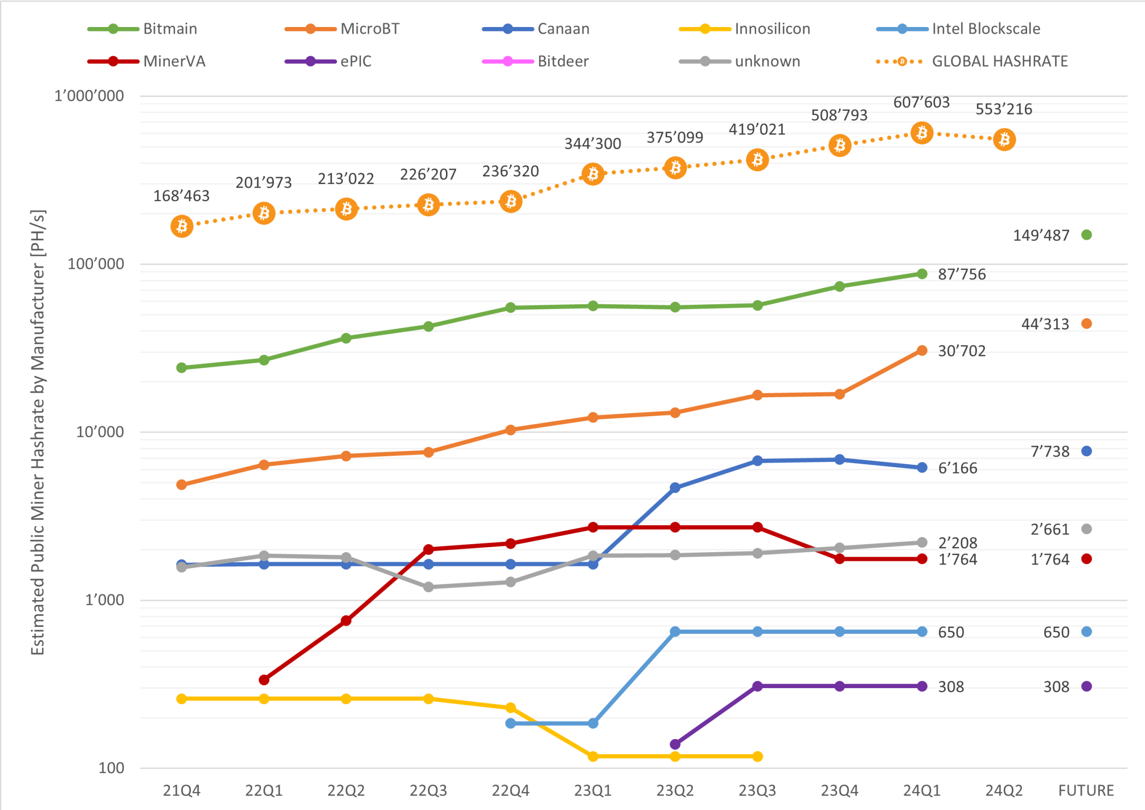
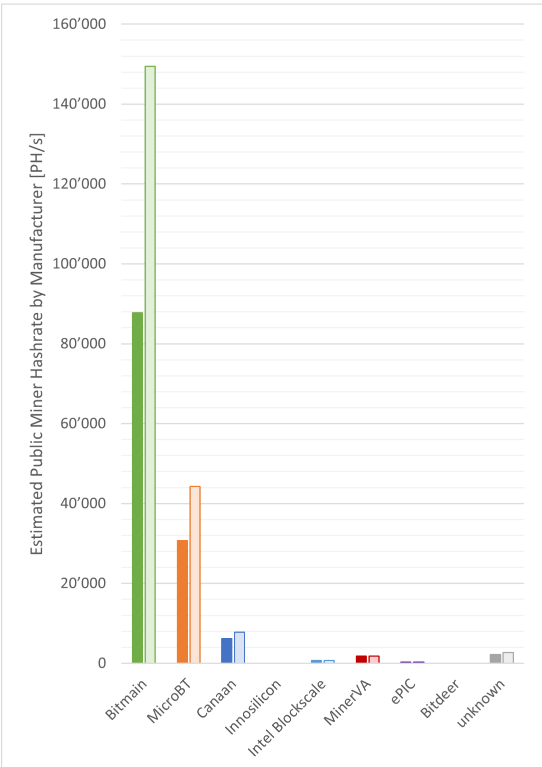


Figure C.4: Hashrate by Manufacturer vs. Bitcoin's Global Hashrate



left (dyed) 24Q1, *right (framed)* FUTURE

Figure C.5: Outlook on Hashrate by Manufacturer

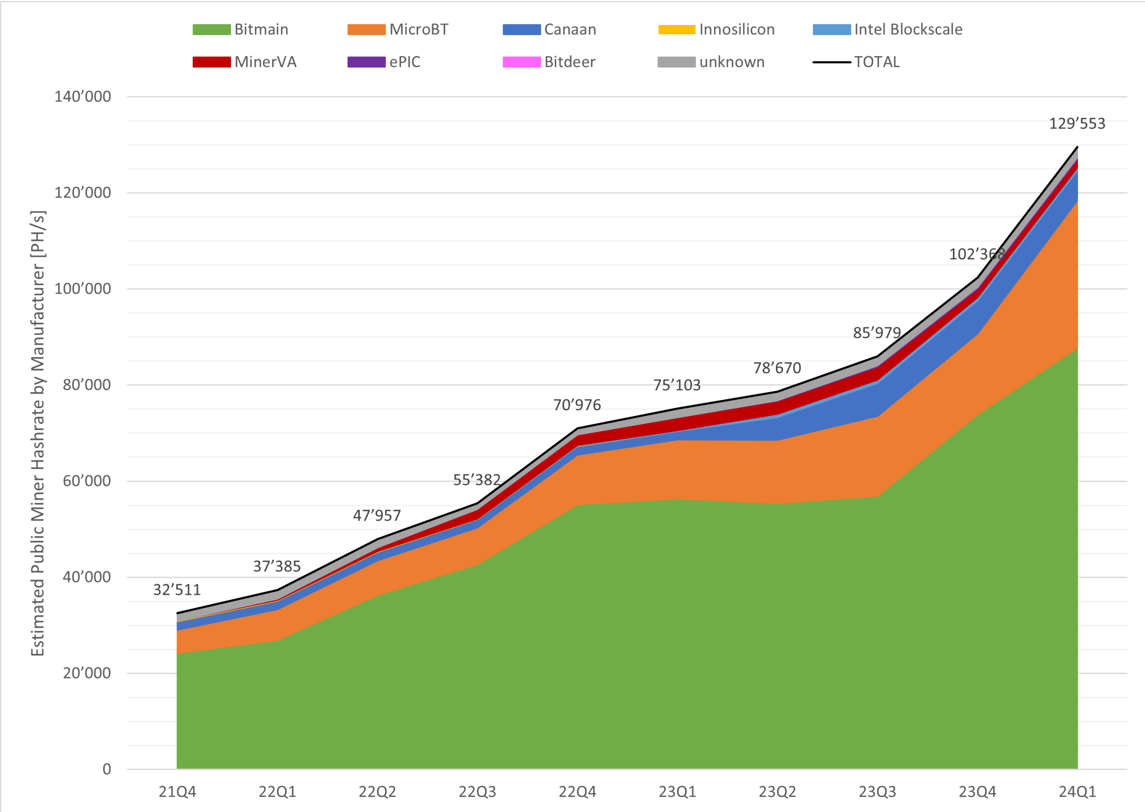


Figure C.6: Hashrate by Manufacturer

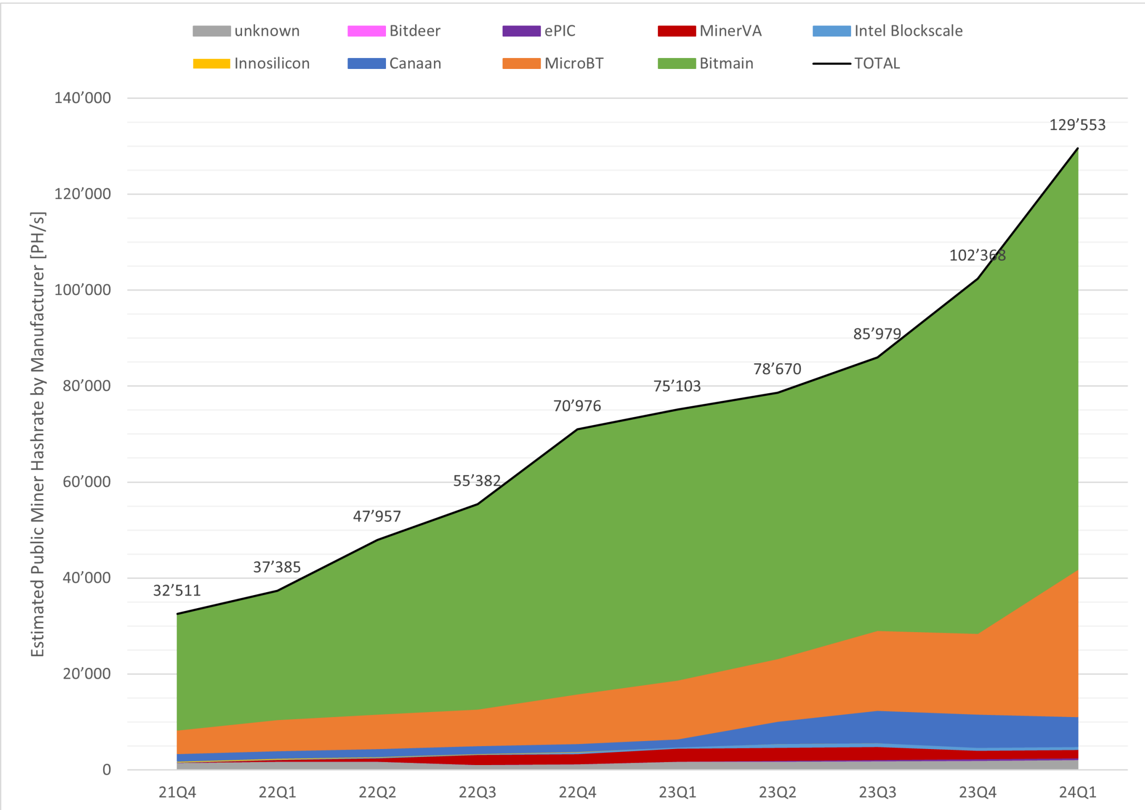


Figure C.7: Hashrate by Manufacturer (inverted)

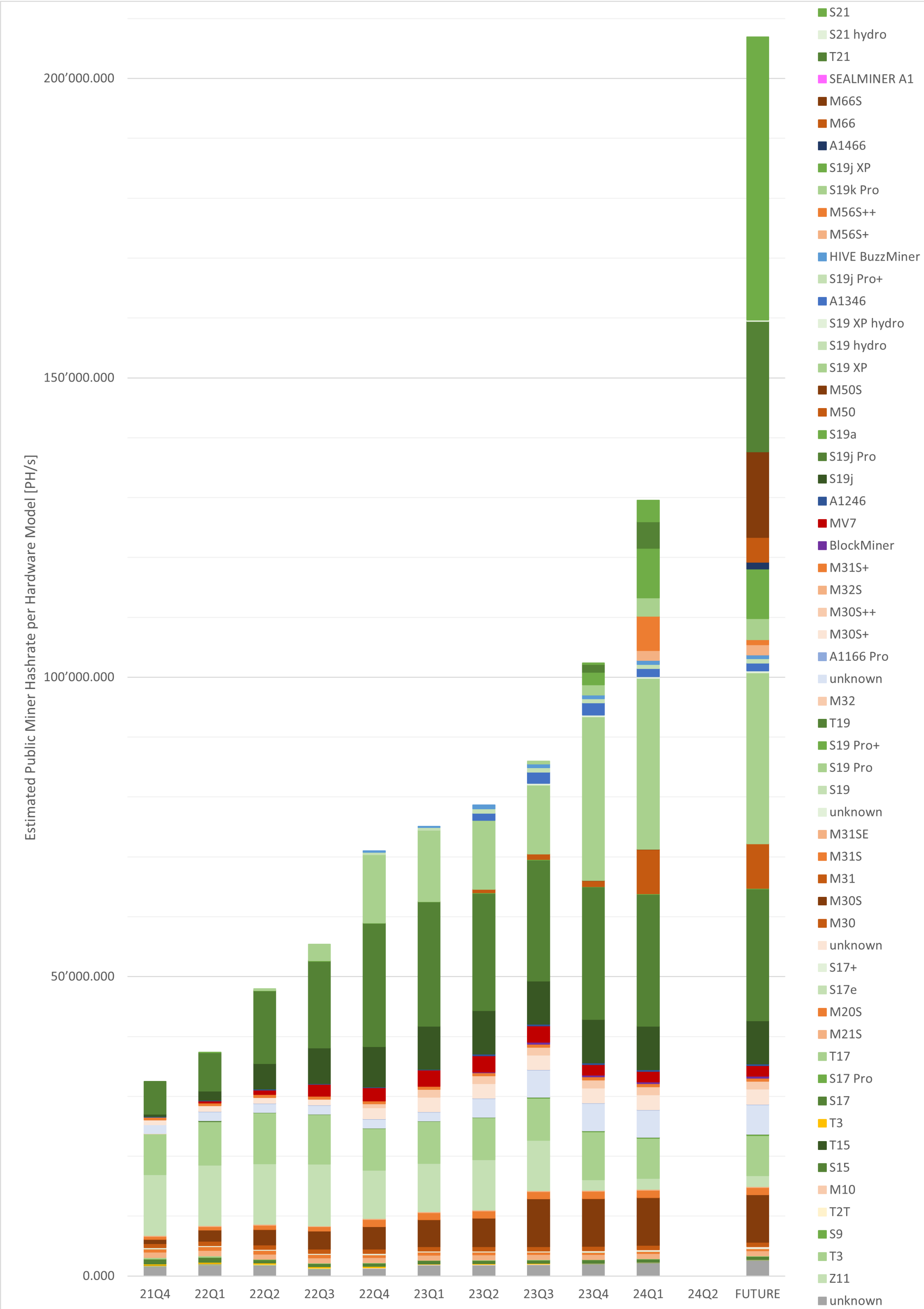


Figure C.8: Stacked Hashrate per Hardware Model with Outlook

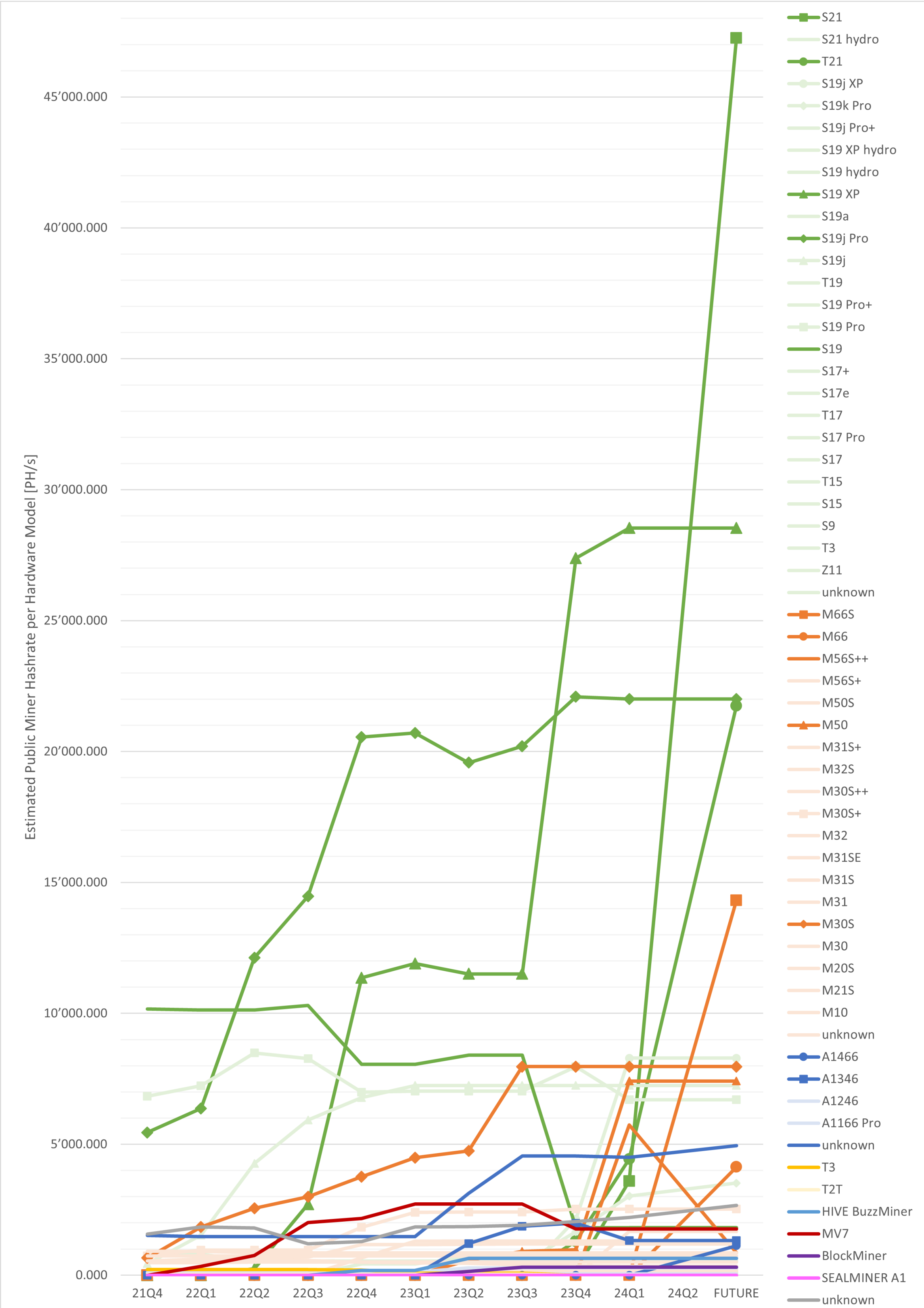


Figure C.9: Hashrate per Hardware Model with Outlook

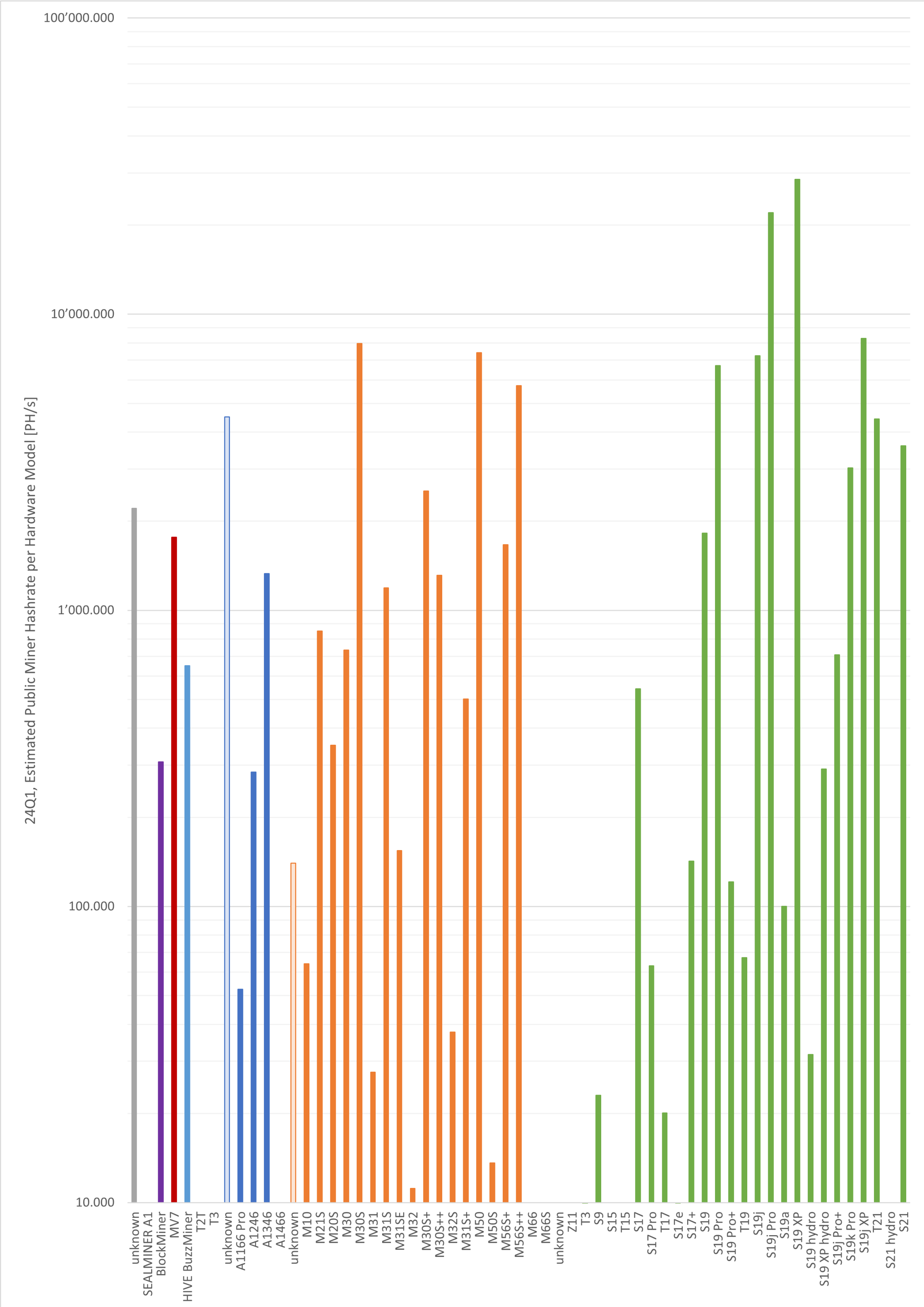


Figure C.10: First Quarter of 2024 Hashrate per Model (logarithmic)

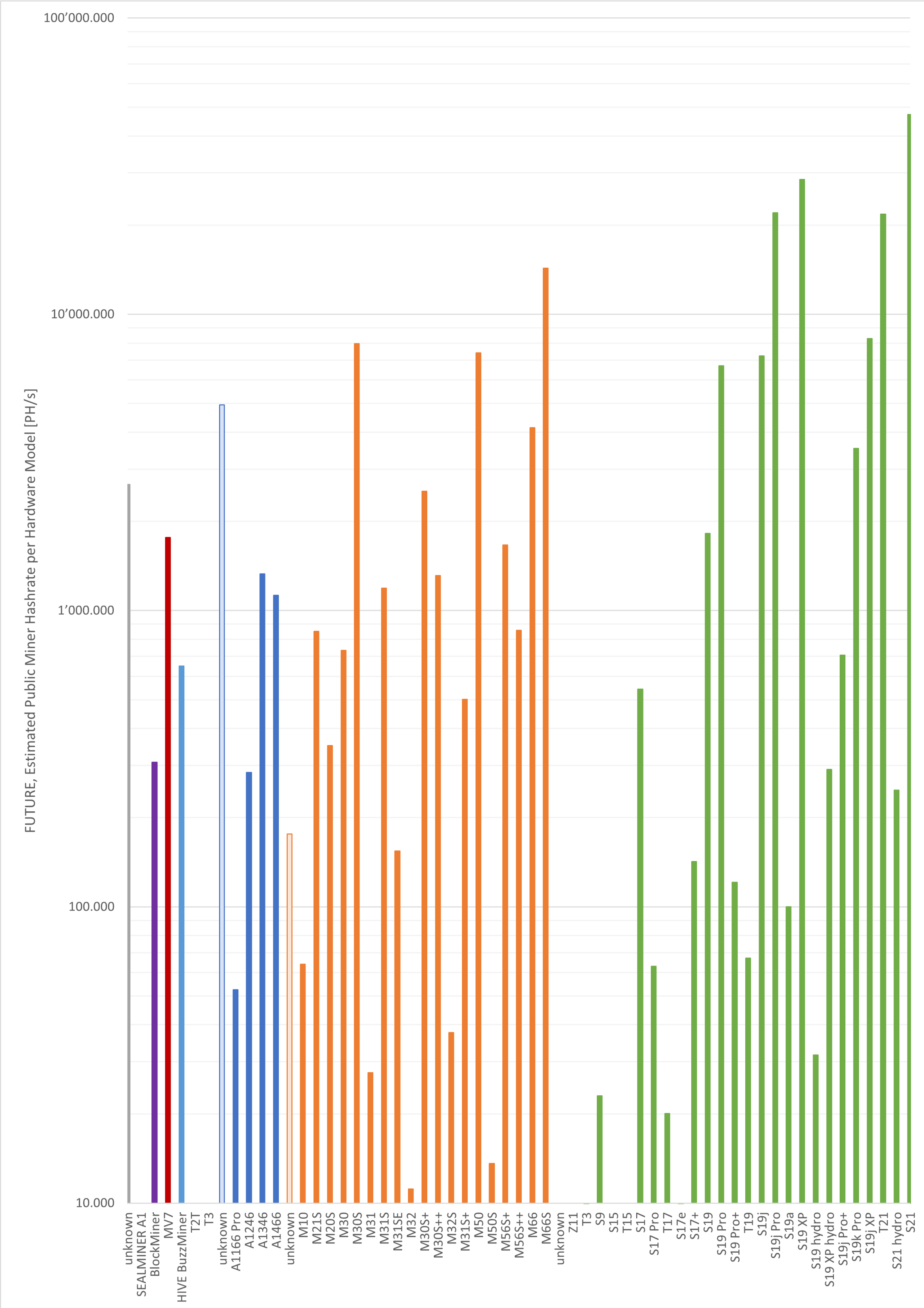


Figure C.11: Outlook on Hashrate per Model (logarithmic)

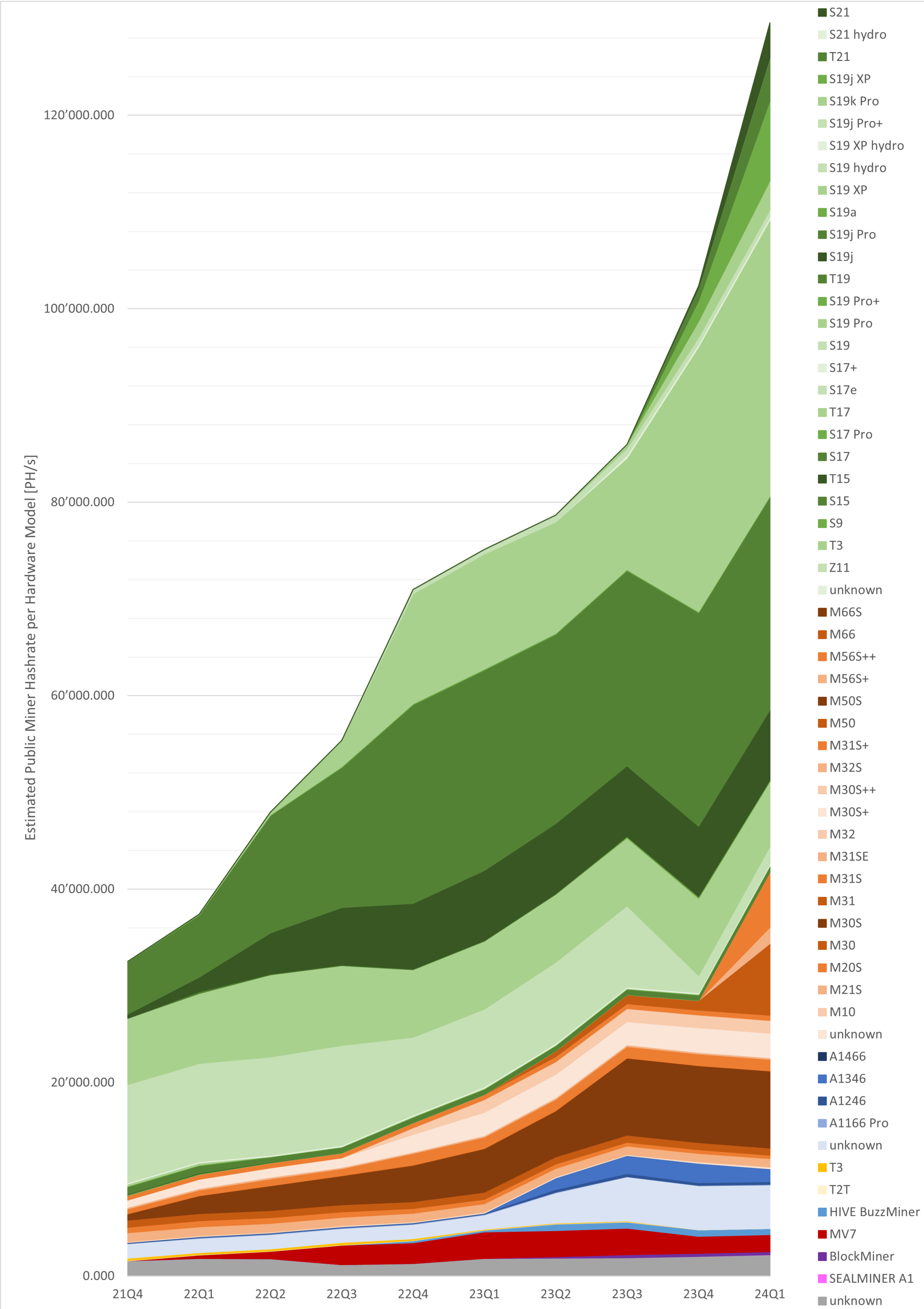


Figure C.12: Aggregated Hashrate per Hardware Model (sorted by manufacturer)

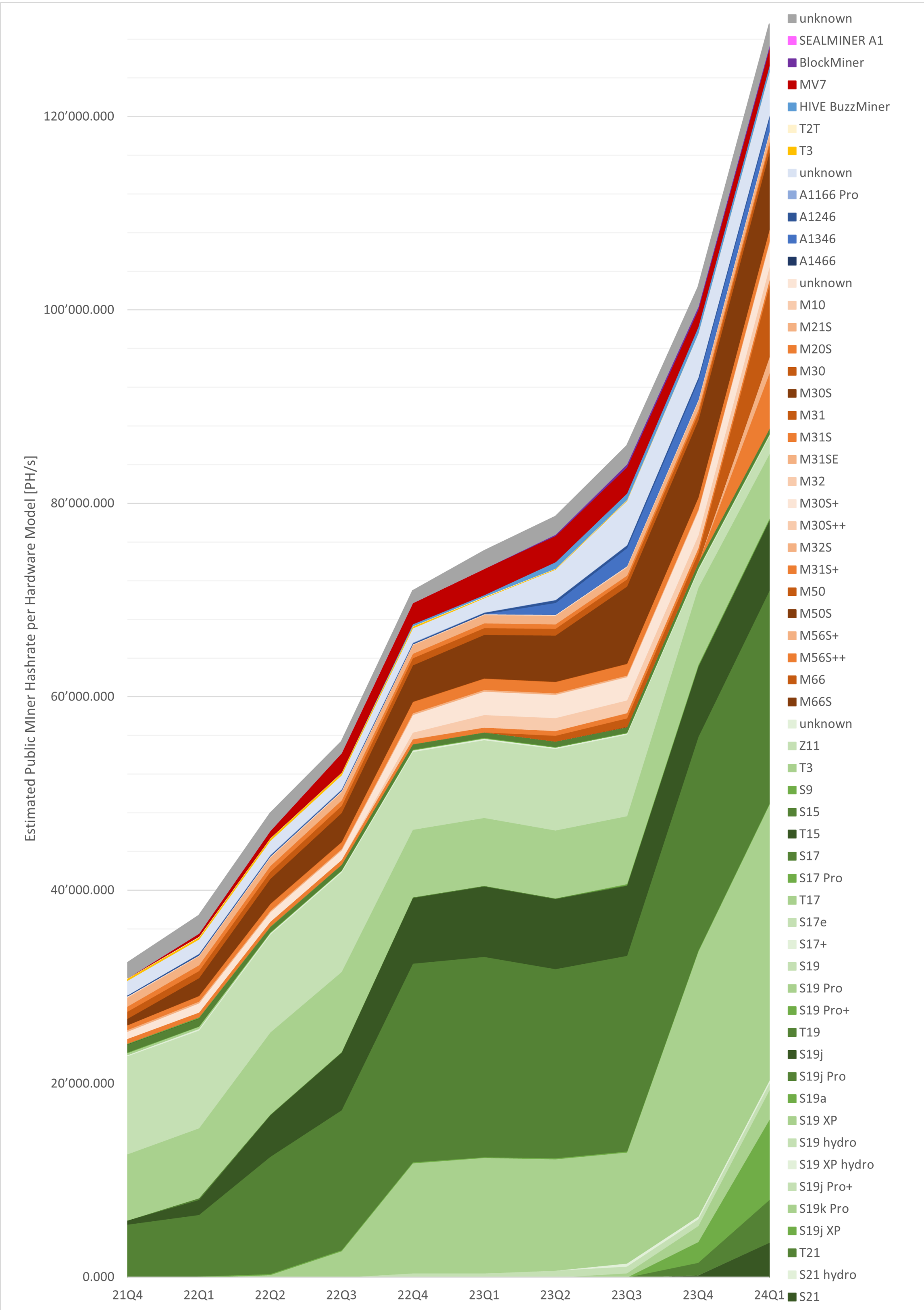


Figure C.13: Aggregated Hashrate per Hardware Model (sorted by manufacturer, inverted)

C.3.2 ASIC Hardware Shares

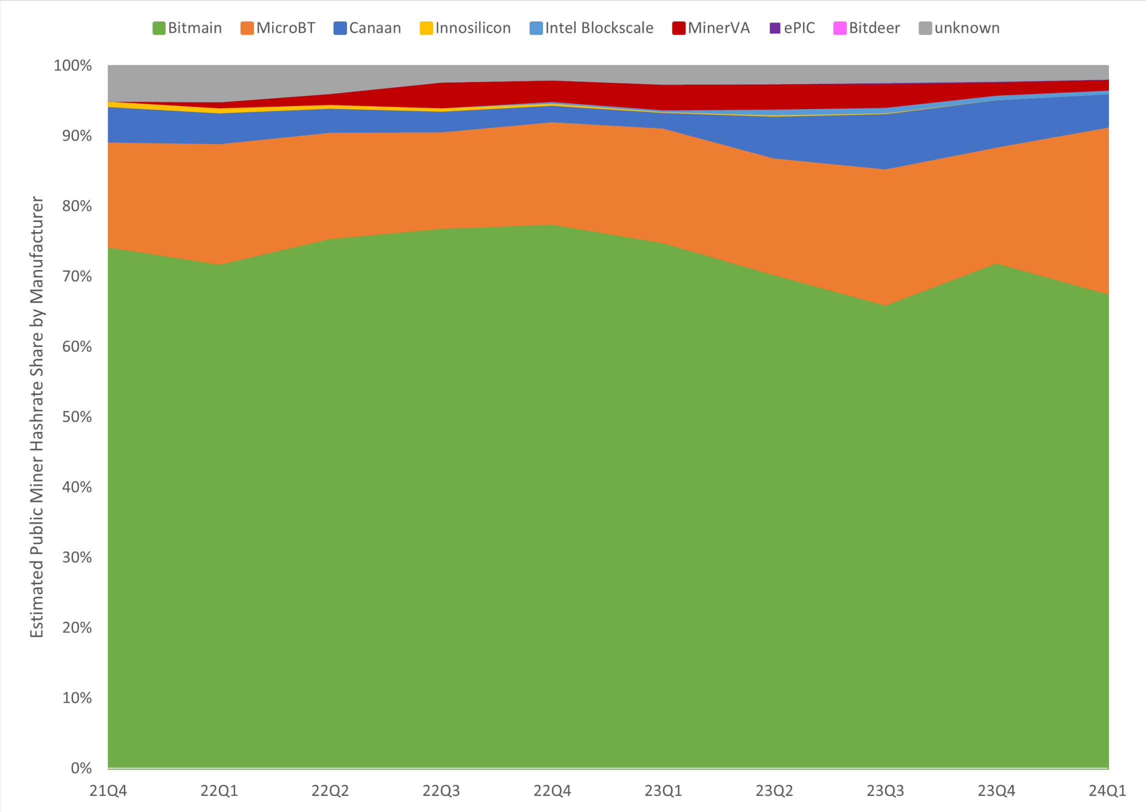


Figure C.14: Hashrate Share by Manufacturer without Outlook

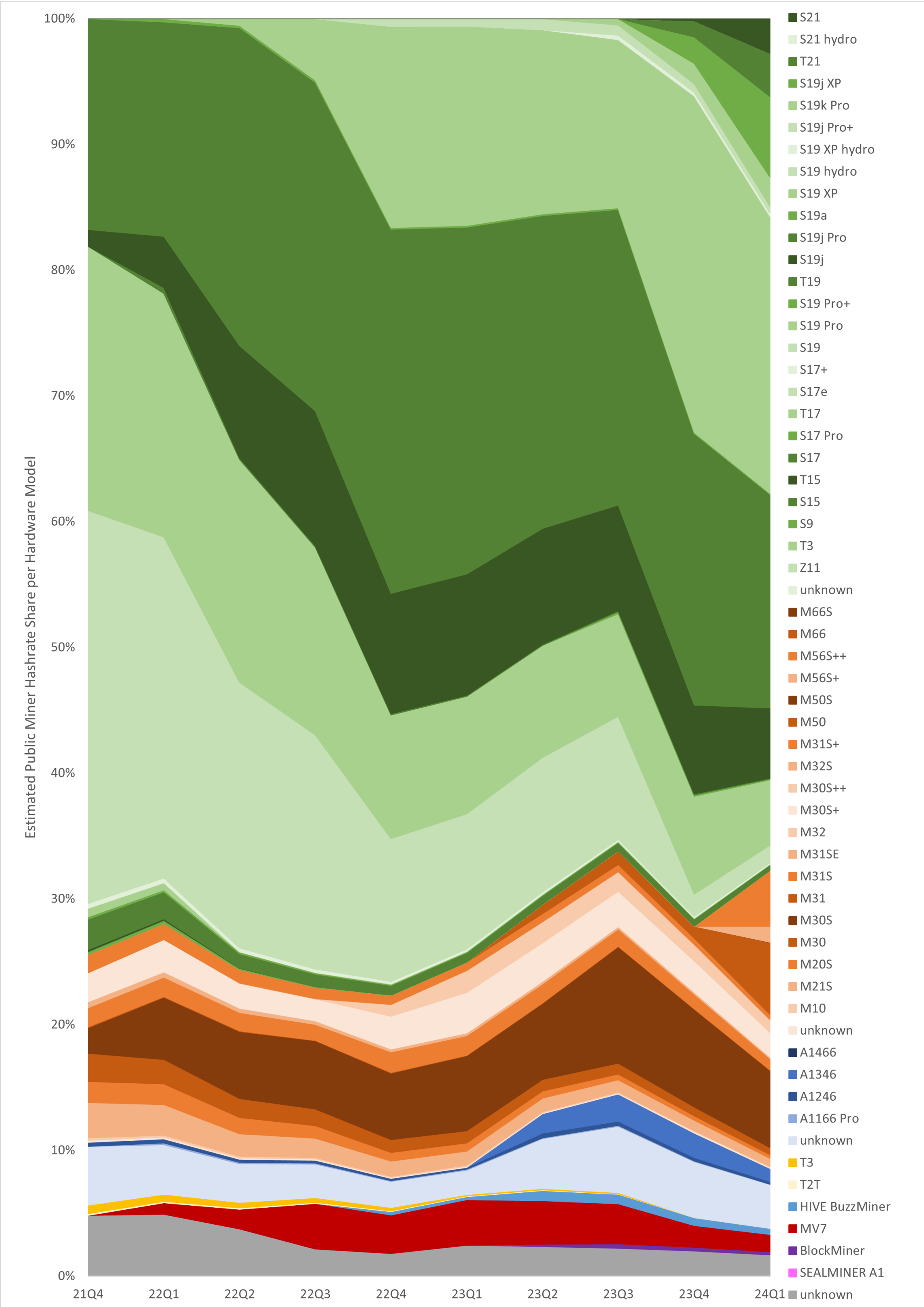


Figure C.15: Hashrate Share per Hardware Model (sorted by manufacturer)

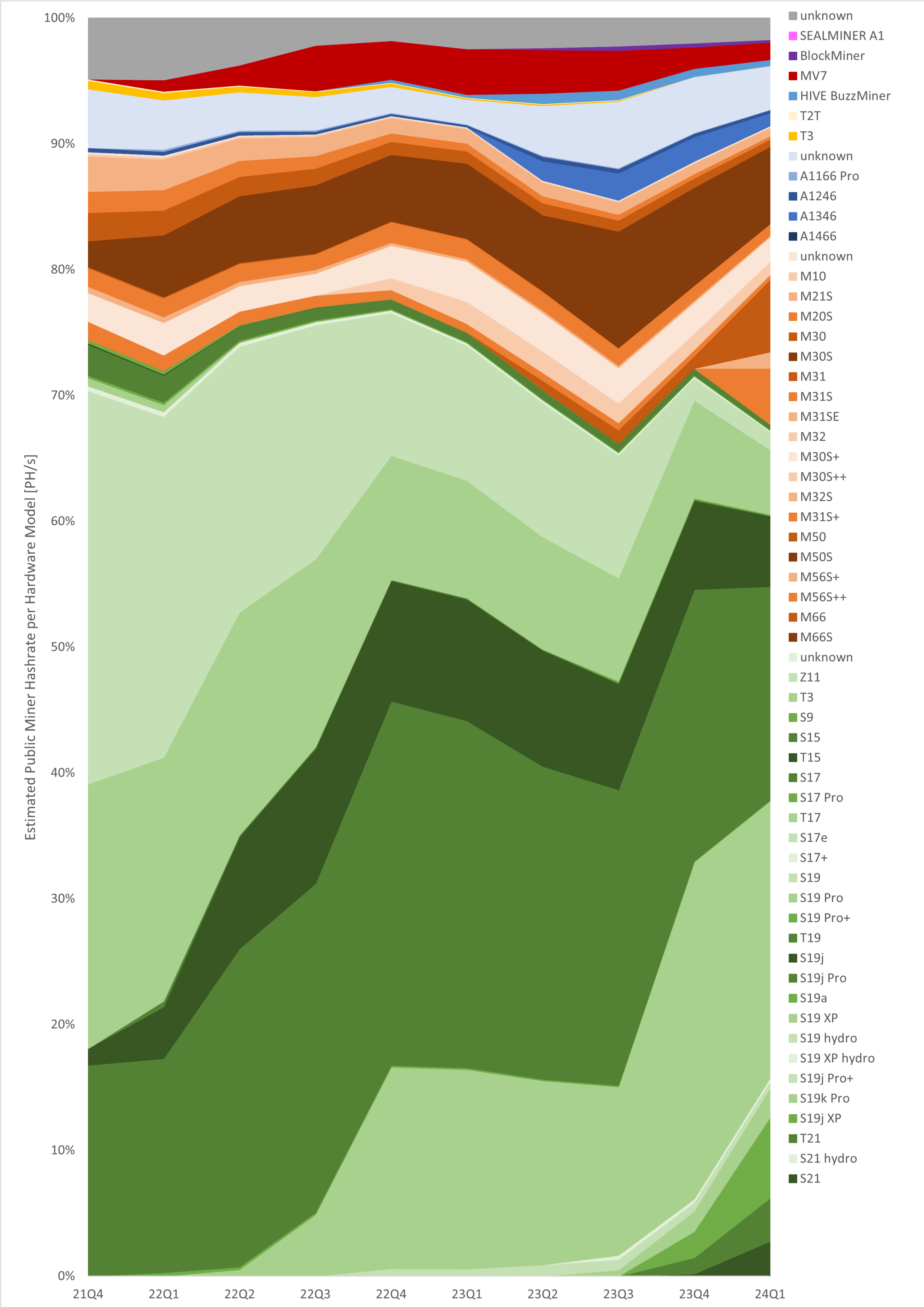


Figure C.16: Hashrate Share per Hardware Model (sorted by manufacturer, inverted)

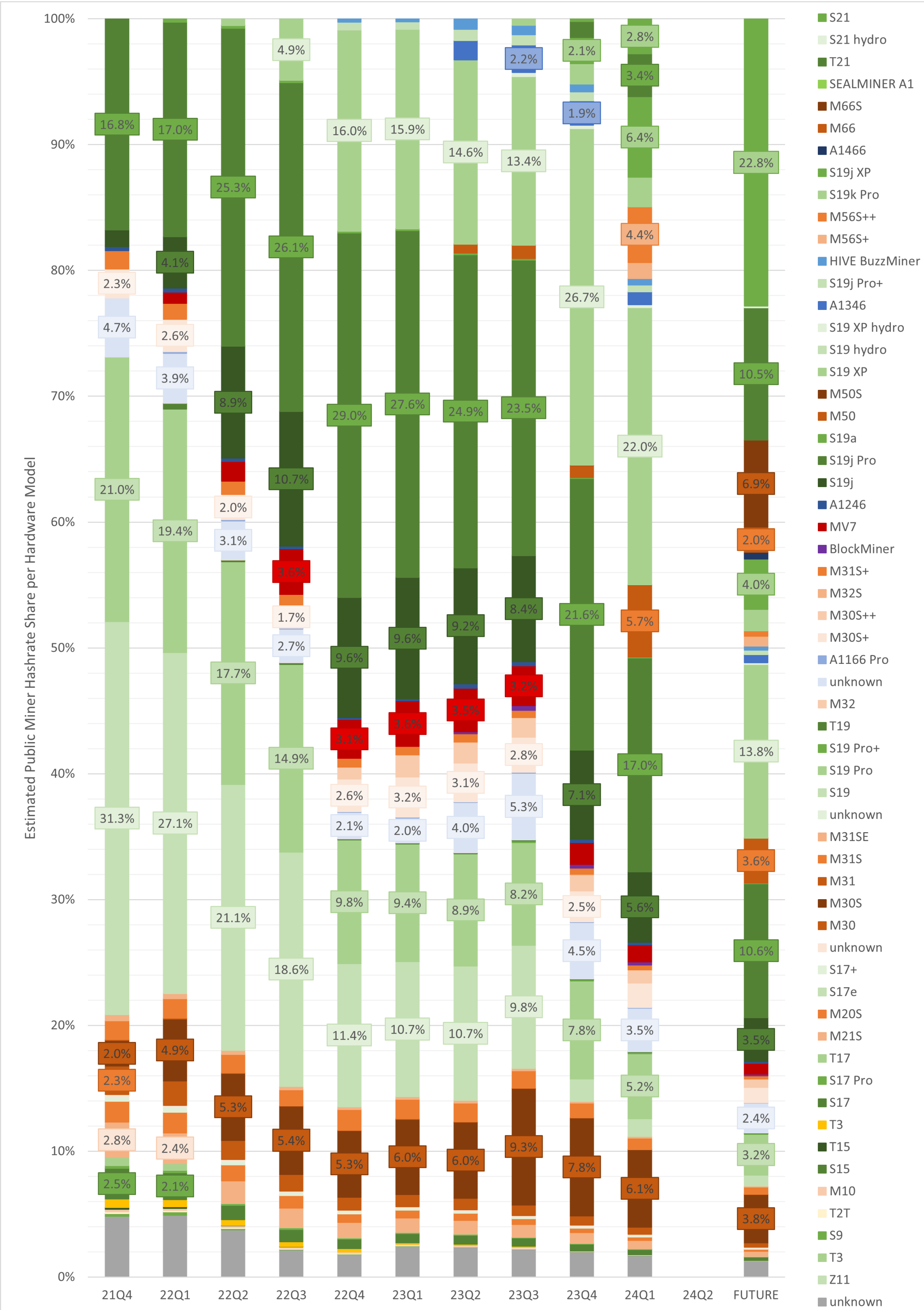


Figure C.17: Dominance per Hardware Model (detailed)

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