Bit Ooda

Bitcoin Power Analysis
Hashrate Implications and Miner Economics

Research

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As of: 7/14/2020
BTC Price: $9220
Target Hashrate: 123.85 EH/s
Current Hashrate: 121.5 EH/s

We attempt to measure, locate and price power capacity, and estimate miner profitability in the context of potential future Hashrate and capital constraints.

We assess that the BTC mining industry utilizes **~65% of 9.6GW** (slide 11, growing at ~10% p.a.) of available power capacity, powering 2.8mm dedicated bitcoin mining rigs. Most current devices are S17 class (slide 48), but future growth will largely come from next-gen S19 class mining rigs (slide 28).

We identified **4.1GW of this power capacity across 153 mining sites**, including power prices at 67 sites representing ~3GW, by speaking with miners, rig manufacturers, resellers and public sources (slide 14).

Our conversations lead us to believe that we have accounted for ~80% of US / Canadian capacity, but just ~15% of Chinese capacity. If accurate, this would imply a **50% market share for China-based miners, followed by the US at 14%** (slide 15).

We assess the median power price at **3c/kWh** (slide 17) and median cash cost to mine BTC at ~$5000 (slide 20). Slide 21 shows S9 class rigs need <2c/kWh power for

viability, while S19s are viable to 9c/kWh.

China's hydro season shifts the cost curve down (slide 23), which supports capital accumulation, BTC price appreciation (slide 25), and subsequent hash growth with a 4-6 month lag (slide 26).

Upgrade cycle could take Hashrate to 360 EH/s in two years and 260 EH/s in 1 year (slide 28), led by available power capacity and the replacement of S9s and S17s by S19 class rigs (slide 30). We have not assessed potential impacts of future rig upgrades.

Increases in Hashrate and difficulty would reduce BTC flow per PH/s (slide 35) and per MWh (slide 37). Miner economics could weaken, needing a BTC price of $21000 to offset the lower BTC flow per PH at 260EH/s, and $29000 to offset 360 EH/s (slide 34). A $1000 price increase is needed to offset each 10EH/s increase in Hashrate (Slide 38).

$4.5B Capex is needed over 12 months, $6.3B to fully fund the upgrade cycle (slide 40). Even with an assumed 35% per annum price appreciation to $15,500 by YE 2021, a $4.1B funding gap remains vs. cash generation (slide 43).

Risks to our thesis

- Price action could reduce funding needs or delay achieving our Hashrate projections. Slide 34 shows revenue sensitivity vs. device cash operating cost at different network Hashrate assumptions.
- Increased access to cheap power could drive Hashrate higher, although limited by diminishing BTC revenue per MWh (slide 37).
- Semiconductor capacity / ASIC shipments could drive variance to our model – although we note that the industry has previously delivered significantly more units than our model assumes (slide 44).

In Summary: Current BTC network power capacity is ~9.6GW (~50% in China, 14% in the US), driving 121EH/s of computing Hashrate. We assess that Hashrate could reach 360EH/s in two years, led by an upgrade cycle, falling median power prices from the current 3c / kWh level, and ~$4.1B external funding into the mining industry. Cheap power, BTC price and semiconductor shipments are key risk factors.

Key Takeaways

- About 50% of 9.6 GW global mining power capacity is likely in China; the US is at ~14%; capacity utilization is ~ 67%

- Median BTC mining power cost is 3c / kWh and cost to mine 1 BTC is ~$5000

- Hashrate could reach 260 & 360 EH/s in 12 & 24 months with upgrade cycle but needs $6.3B Capex; funding gap is $4.1B vs. industry cash generation

- Price needs to appreciate by $1000 for every 10EH/s increase to stay revenue neutral per MWh

- Cheap power, BTC price and semiconductor shipments are key risk factors to our estimates

Foreword
The Importance of Bitcoin Mining Research

Bitcoin is a digital commodity that spurred the emergence of a new asset class. One of the defining characteristics of this new asset class is that ownership of the asset's units is recorded on a distributed ledger.

Bitcoin miners update the Bitcoin ledger (i.e., add new blocks of transactions to the ledger) by operating costly, specialized hardware and consuming large amounts of energy. By doing so, miners perform transaction settlement and secure the ledger. As such, Bitcoin mining is a foundational component of the network and Bitcoin as an asset. Despite its importance, mining has been among the least transparent and the least understood part of the broader Bitcoin ecosystem.

Miners are not required to register and get a license to be part of the Bitcoin network – the system is permisionless and that is what makes it robust, more decentralized, and ultimately secure. Due to its open and pseudonymous attributes, it is not possible to directly observe the actual composition of the mining network – by location, size and type of operation, equipment used, or the economics and profitability. All of this is important macro data that would help us understand the state and health of the system and identify trends and make predictions on how it may be evolving .

This report by BitOoda serves to improve the transparency related to the composition of Bitcoin miners. BitOoda leveraged its extensive network to survey 67 mining sites. This data, combined with secondary research of publicly available data, allowed them to locate a total of 153 mining sites with operations in 20 countries, comprising more than 40% of the global network Hashrate. Although further assumptions had to be made, this valuable dataset allowed them to draw some interesting insights such as Bitcoin's global production cost curve, the network's total power consumption, and is useful in making predictions about the network Hashrate growth.

While no research report about the state of Bitcoin mining can draw definitive conclusions, research studies with transparent and sound methodologies like this shed more light on the industry. When the results from multiple such independent studies are combined, one can make conclusions about the mining ecosystem with more confidence.

Fidelity Center for Applied Technology (FCAT) started mining bitcoin in 2014 with research as our main objective. In 2018, we organized the Mining Summit, a two-day, free and public event, with the goal of sharing our learnings and educating the broader community about the state and

importance of mining. This year we decided to sponsor this research project conducted by BitOoda centered around the power cost analysis for the Bitcoin mining network.

We look forward to continuing our research of the Bitcoin mining space and helping to push the ecosystem forward. We thank the BitOoda team for their work, which we hope will elevate everyone's understanding about this complex and fascinating part of the Bitcoin ecosystem.

Juri Bulovic
Fidelity Center for Applied Technology

About Us:

BitOoda:

Founded in New York in 2017, BitOoda set out to become the leading digital asset fintech firm. The company was created to deliver transparency and accelerate the global adoption of transformational technologies by promoting efficient marketplaces through innovative and professional capital markets solutions. Founders Tim Kelly and Rob Madden leveraged their expertise to create a financial technology and services firm that aims to evolve digital asset markets through an **innovative data-driven platform** that offers **next-generation financial products, high-touch brokerage services,** and **applied research solutions** that put our clients' interests first.

Today, BitOoda has become a pioneer in the digital finance space. We have:

- Established a brand as an authority for institutional solutions in the digital economy through product engineering – including our proprietary BitOoda Hash™ Bitcoin Hashpower Contract, BitOoda Difficulty™ Swap and BitOoda Transaction Fee™ products.

- Developed an industry-leading distribution & execution capability in our role as an Agency-only broker, including building foundational relationships with firms across the digital asset ecosystem, including funds, projects, data centers, capital markets participants, and service providers.

- Led the digital asset community's regulatory development through our SEC-regulated Broker Dealer, our CFTC-regulated Introducing Broker, and our principal leadership role as a founding member of the Association for Digital Asset Markets (ADAM), a trade group focused on defining industry standards for the advancement of fair and orderly markets.

- Applied advanced technologies and data analytics to design a suite of proprietary data products and indices that give our clients unique advantages to optimize their positions and manage risk.

For more information on BitOoda, please visit our website or contact us at info@bitooda.com

Sam Doctor:

Sam Doctor, the principal author of this report, is Chief Strategist at BitOoda.

Sam Doctor's flagship research includes both project evaluations and Bitcoin mining analyses focused on Bitcoin mining profitability and risk factors. His aim, as the Chief Strategist at BitOoda, is to apply a variety of capital markets tools to enable investors and projects to reduce risk, enhance returns and overcome barriers to adoption.

Mr. Doctor is a veteran finance professional with over 18 years research experience, covering technology stocks, macro and quantitative strategy and cryptocurrency research, formerly at JPMorgan in New York and Asia, and more recently as the Head of Data Science and Quant Research at Fundstrat Global Advisors.

Mr. Doctor holds a Finance & Strategy MBA from the prestigious Indian Institute of Management, Ahmedabad and is an Electronics and Semiconductor engineer from the University of Mumbai, India. He holds his Series 7, 63, 86 and 87 licenses with FINRA .

More information is on his LinkedIn page.

Analyzing the Bitcoin Network

Research Methodology
The BitOoda Hash Dashboard
Network Power Capacity
Miners' Geographic Distribution
Mining Cost Curves
Effects of China's Hydro Season
Future Outlook for Hash
Price, Power and Production Capacity Constraints
Appendix and Sources

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Research Methodology

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The Bitcoin Network:
Demystifying Mining

Bitcoin mining is a secretive industry, with very little publicly available information. We find that even many sophisticated crypto investors have gaps in their understanding of mining and potential investment opportunities in the space. Despite stellar research by Coinmetrics, Coinshares, and the Cambridge Center for Alternative Finance, unanswered questions remain. This research has been commissioned by Fidelity Center for Applied Technology (FCAT) and independently conducted by BitOoda. **We aim to add to the existing body of research, building upon prior research and attempting to address new questions.**

Research Objectives

In this research project, we set out to answer some of the age-old questions around Bitcoin mining, starting with how much power does the network draw; how much power can it currently draw and how this capacity is growing.

We also aim to identify the distribution of mining capacity globally, both by geography and by the cost of power, with an aim to develop a power cost and Bitcoin mining cost curve, based on bottom up survey research.

Further, we aim to identify the available computing or Hashpower in the mining network, and estimate how much it could grow in the coming 24 months or so. Additionally, we model the capital investment entailed in achieving this Hashrate, and the constraints involved – semiconductor capacity, internal cash generation by the mining industry, diminishing returns with rising Hashrate (a function of the price of Bitcoin) and available external funding.

Methodology

We spoke with every miner and rig manufacturer

and reseller we could identify (more than 60 conversations), requesting data on facility size, location, and power price, while promising anonymity, which is critical to this highly secretive community. Power price is the single largest industry cost, and a primary source of competitive advantage.

In addition, we surveyed 45+ public sources such as company websites, press releases and media interviews with miners to piece together what information we could obtain.

We gathered size and country data on 131 miners (153 sites across 20 countries), totaling 4GW of available power. Of these, we obtained power prices on 66 sites, either as a point estimate – such as 1.8c / kWh or a range (e.g. between 2-3c/kWh), totaling about 2.9GW of available power capacity. We also did research into the impact of China's hydro season on the mining community – with surprising results.

We used this data to build a cost curve of power price for the known capacity, and a curve representing the cash cost to mine 1 Bitcoin, making standardized assumptions such as a power usage effectiveness factor of 1.12. (For every unit of power used to mine Bitcoin, 12% excess is consumed for everything else – cooling, lighting, routers / switches and other facility power overhead.) We then plot out the percentage of Bitcoin mined at different cost levels, based on the distribution of power prices.

Additionally, we modeled what we believe is a lower bound for the aggregate power capacity in the Bitcoin network of 9.6GW, and estimated that it could grow at a minimum of 10% a year, using simplifying assumptions detailed in the report.

Finally, we examined the potential network Hashrate if all the available electricity in the network powered latest-generation rigs, and its security implications. We then estimate the capital investment required to achieve that potential Hashrate, as well as the funding gap – external funding required to bridge the difference between the capex need and the internal cash generation within the network. We take note of the key constraints to Hashrate growth: available cheap electricity, capital availability, equipment availability, lead times and production constraints, and the impact of BTC price on the value of diminishing BTC rewards per production unit as the network grows.

We conclude with our 18-24 month outlook for the Bitcoin Mining Network.

Takeaways

- Current BTC network power capacity is ~9.6GW (~50% in China, 14% in the US), driving 121EH/s of computing Hashrate.

- We assess that Hashrate could reach 360EH/s in two years, led by an upgrade cycle, falling median power prices from the current 3c / kWh level, and ~$4.1B external funding into the mining industry.

- Cheap power, BTC price and semiconductor shipments are key risk factors.

- **We do NOT make any price forecasts, and merely use different price scenarios to model potential impacts on network Hashrate and miner profitability and capital investment.**
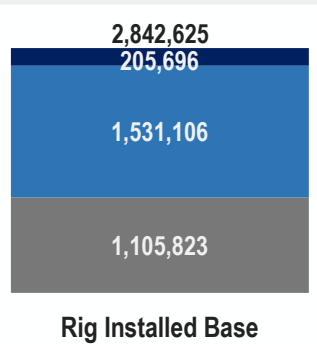
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Bitooda Hash™
Dashboard

- A regular publication that shows the state of the Bitcoin mining network: Price, Hashrate, Number of Blocks mined, Difficulty, and other metrics.

- We show the expected revenue per PH/s Day and per MWh as a measure of miner profitability.

- Our model shows estimated power cost curves and Bitcoin mining cost curves, as well as the cost to mine 1 BTC using different generations of mining rigs, at different power prices.

- We further plot our model estimates of network Hashrate, power consumption, installed base of mining rigs by generation, and revenue curves per MWh for each generation of rig, at different network Hashrate.

- Finally, we end with our estimates of the geographic distribution of mining capacity and our projections of the network Hashrate.

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BitOoda Hash™
Dashboard

Sam Doctor Research

AS OF:
08:00 AM ET
July 14, 2020

$ 9220 ▼ 1%
BTC Price

121.5 EH/s ▲ 1.9%
Hash Rate

147 Blocks ▲ 3
Blocks Mined

16.5T ▼ 5%
Next Diff. est.

Daily BTC / PH/s
0.0075BTC ($70)

BTC / MWh
S9 Class: 0.0027BTC ($25)
S17 Class: 0.0058BTC ($54)
S19 Class: 0.0095BTC ($88)

BTC Network Power Cost Curve

Known
Lower Bound
Upper Bound

We believe 50%+ of Hashrate is currently at under 3c / kWh power

Cash cost to mine 1 BTC

$10/MWh $20/MWh $30/MWh $40/MWh $50/MWh $60/MWh $70/MWh $80/MWh $90/MWh $100/MWh

S9 Class
S17 Class
S19 Class
BTC Price

BTC Production Cost Curve

Known Data
Upper Bound
Lower Bound

Hashrate
123850 PH/s
22627 PH/s
85742 PH/s
15482 PH/s

Power Consumption
6423 MW
669 MW
4128 MW
1627 MW

Rig Installed Base
2,842,625
205,696
1,531,106
1,105,823

Mining Stats: BitOoda Ests
- S19 Class
- S17 Class
- S9 Class

Revenue per MWh
S9 Class Current BTC Price +/- $1000 Band
S17 Class Band
S19 Class Band
Revenue @123.85 EH/s and BTC Price of $9220

88
54
25
124 EH/s

Known Capacity (BitOoda Est)
Canada 613 MW
Russia 465 MW
China 731 MW
Kazakhstan 455 MW
Iran 450 MW
USA 1116 MW
Rest of World 91 MW
Iceland 165 MW

Est. capacity share known
USA 85.0%
China 15.0%
Canada 85.0%
Russia 60.0%
Kazakhstan 60.0%
Iran 60.0%
Iceland 90.0%
Rest of World 33.2%

Distribution of Total Capacity
China 50%
Canada 7%
Kazakhstan 8%
Iran 8%
USA 14%
Iceland 2%
Rest of World, 3%

Hashrate Projections: 260 EH/s in 12, 360 EH/s in 24 months
S9 Class
S17 Class
S19 Class

5/17/20 7/17/20 9/17/20 11/17/20 1/17/21 3/17/21 5/17/21 7/17/21 9/17/21 11/17/21 1/17/22 3/17/22 5/17/22 7/17/22

Metrics assume Bitmain S19 as a representative net-gen device, unless specified

Source: BitOoda, Coinmetrics, Kaiko, EIA

Network
Power Capacity

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Understanding Miner Economics amid Stagnant BTC Price

- Bitcoin price was range bound through the block reward halving in May 2020
- Hashrate peaked just prior to the event, and has yet to fully recover from the crash immediately afterward. Mining economics have weakened considerably
- **This report attempts to measure, locate and price power capacity and forecast changing miner profitability in the context of potential future Hashrate and capital constraints**
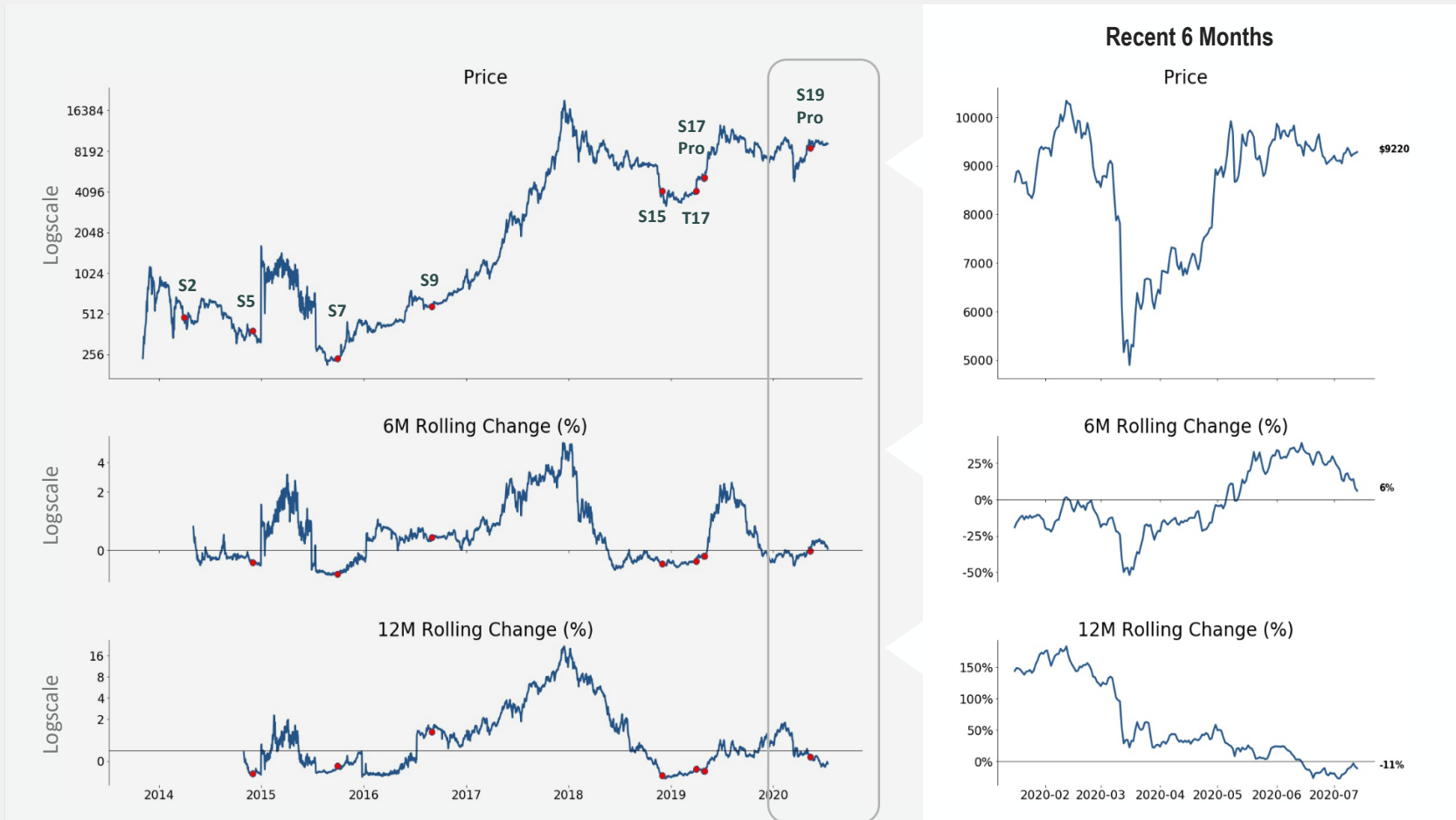
Figure: Bitcoin price and rolling changes
Note: Since 2014; data as of 7/14/2020

At least 9.6GW available
to BTC mining network

- The Hashrate peak in early May needed 9.6GW of power consumed by the Bitcoin mining network, assuming capacity shut-ins that took Hashrate down to 82EH/s by mid May were all older generation rigs
- **The Hashrate bottom corresponds to just 3.9GW of power draw**

136098 PH/s

S17 Class 81659 PH/s

S9 Class 54439 PH/s

Hashrate May 10

1 Hashrate fell in the week of the BTC halving

2 We assume all 54EH/s lost was older gen S9s

81659 PH/s

S17 Class 81659 PH/s

Hashrate May 17

3 It would take 3.9GW to power 82 EH/s using only S17 class equipment

9651 MW

S17 Class 3931 MW

S9 Class 5720 MW

Power Consumption May 10

4 5.7GW = 54 EH/s of S9 class rigs

5 Implied power usage fell from 9.6 to 3.9GW

3931 MW

S17 Class 3931 MW

Power Consumption May 17

Figure: Bitcoin Hashrate and power consumption at recent peak / trough
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

Hashrate of 124EH/s implies 6.4GW and 2.8mm devices in operation

- Capacity utilization is 67% of available power
- New devices drive efficiency gains
- **The upgrade cycle to S19 class rigs should drive hash growth, which we examine in detail in the Future Outlook section**

Next-gen rigs = 18% of Hashrate => 10% of power consumption => 7% of operating devices

123850 PH/s

22627 PH/s	S19 Class
85742 PH/s	S17 Class
15482 PH/s	S9 Class

Hashrate

6423 MW

669 MW
4128 MW
1627 MW

Power Consumption

2,842,625

205,696
1,531,106
1,105,823

Rig Installed Base

Mining Stats:
BitOoda Ests

■ S19 Class
■ S17 Class
■ S9 Class

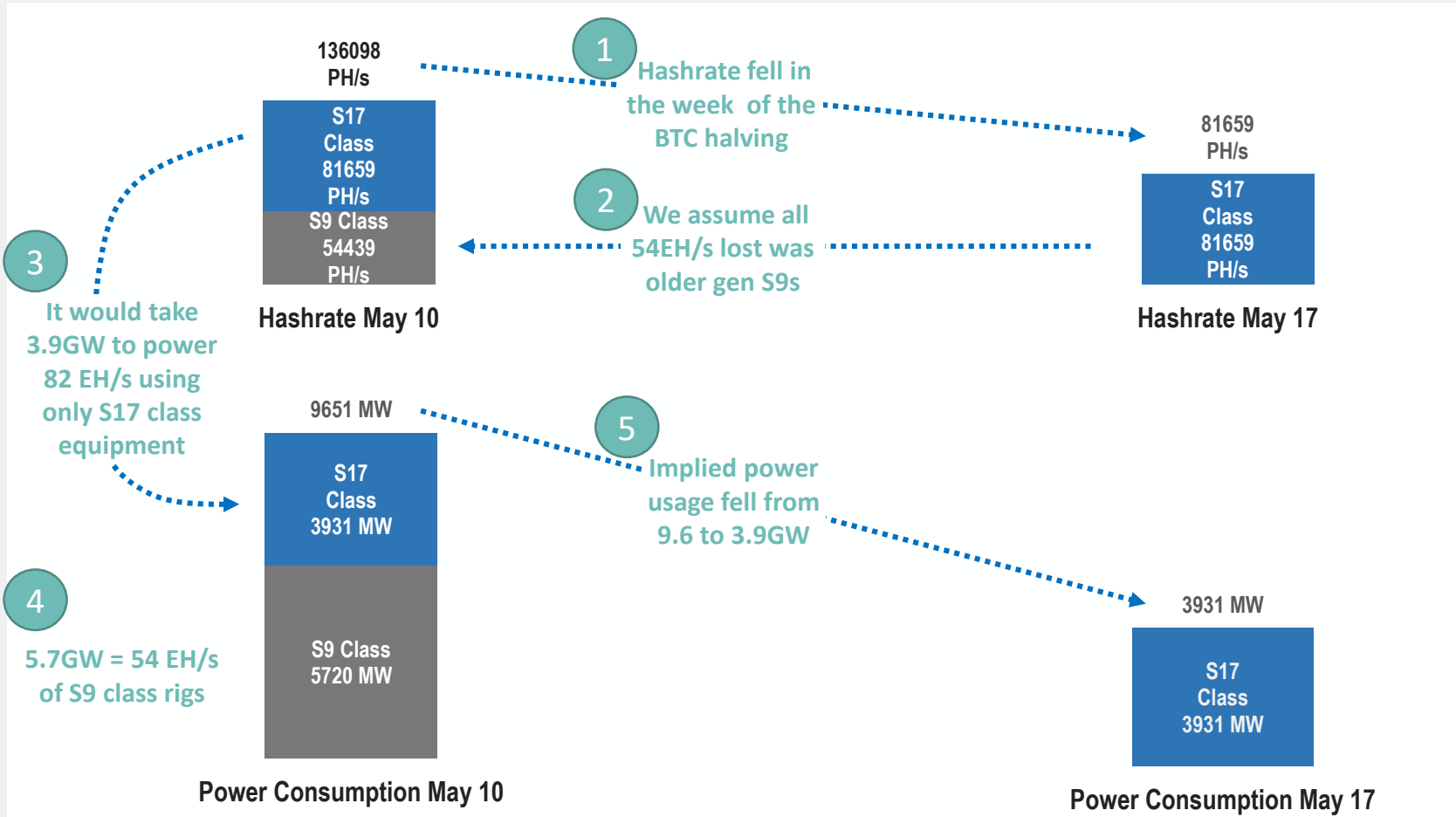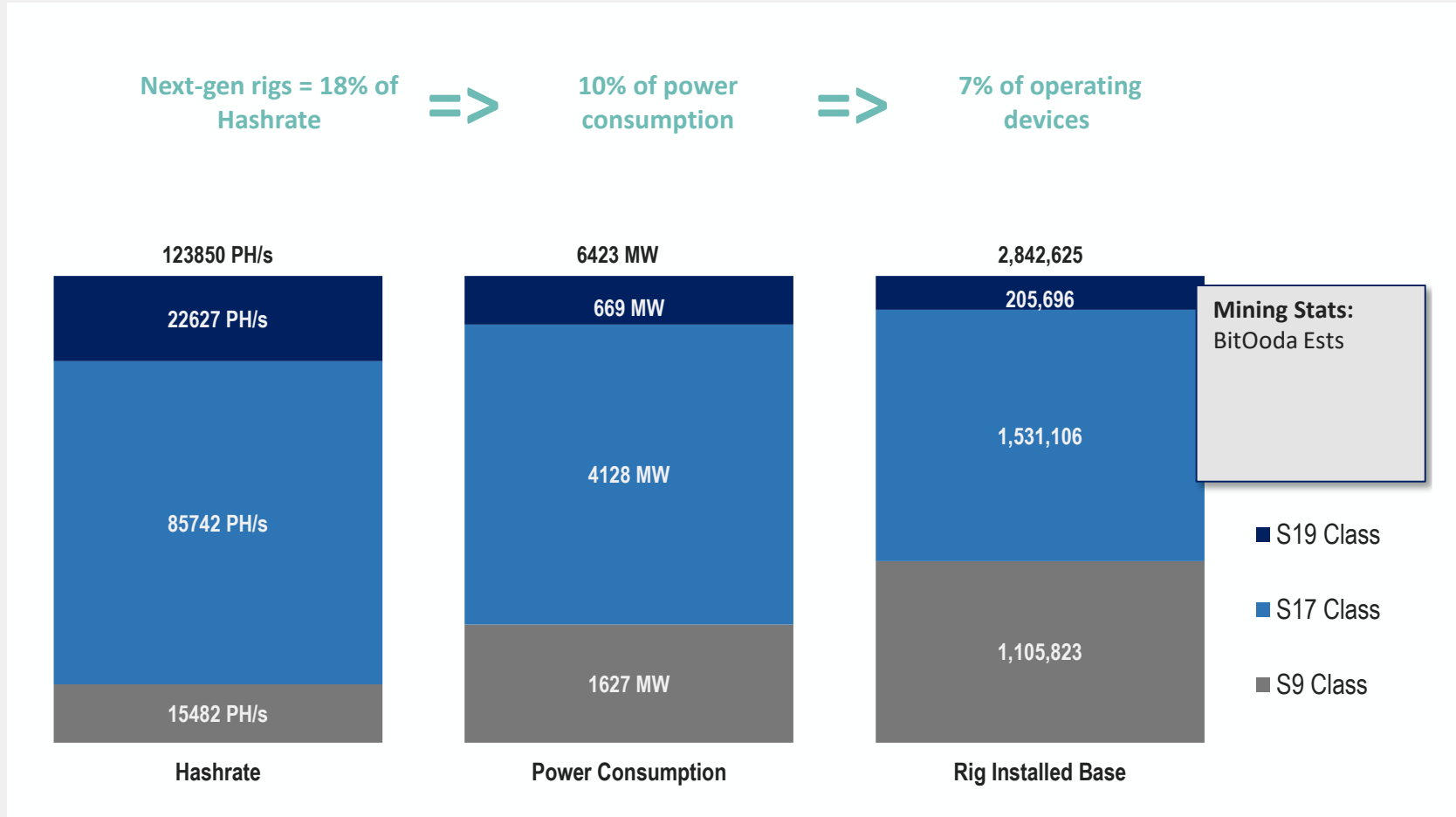**Figure:** Bitcoin Hashrate, power consumption and installed base of rigs
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

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Miners' Geographic Distribution

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Bottom up research identifies geographic distribution of 4.1GW of Mining Capacity

- We identified about 4.1GW of power through bottom-up research, including direct conversations with miners, rig manufacturers / dealers, and public sources such as filings, press releases and miner interviews
- Our data spans 153 mining sites, skewed towards the US and Canada
- Of these 153, we have power prices for 67, totaling ~3GW of capacity

Figure: Geographic distribution of surveyed mining capacity

Note: Some of the underlying data was shared under condition of anonymity

As of 7/14/2020

Source: BitOoda estimates, Miners, ASIC makers/ resellers, public sources

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Geographic Distribution:
Estimated Network Power Capacity

- Based on conversations with individual miners and resellers, we assess that about 80-90% of US, Canada and Iceland-based mining capacity has been identified, but perhaps just 15% of Chinese capacity
- Applying these rough estimates, we believe China represents 4.9GW or 50% of all available power for Bitcoin Mining, followed by the USA (14%)

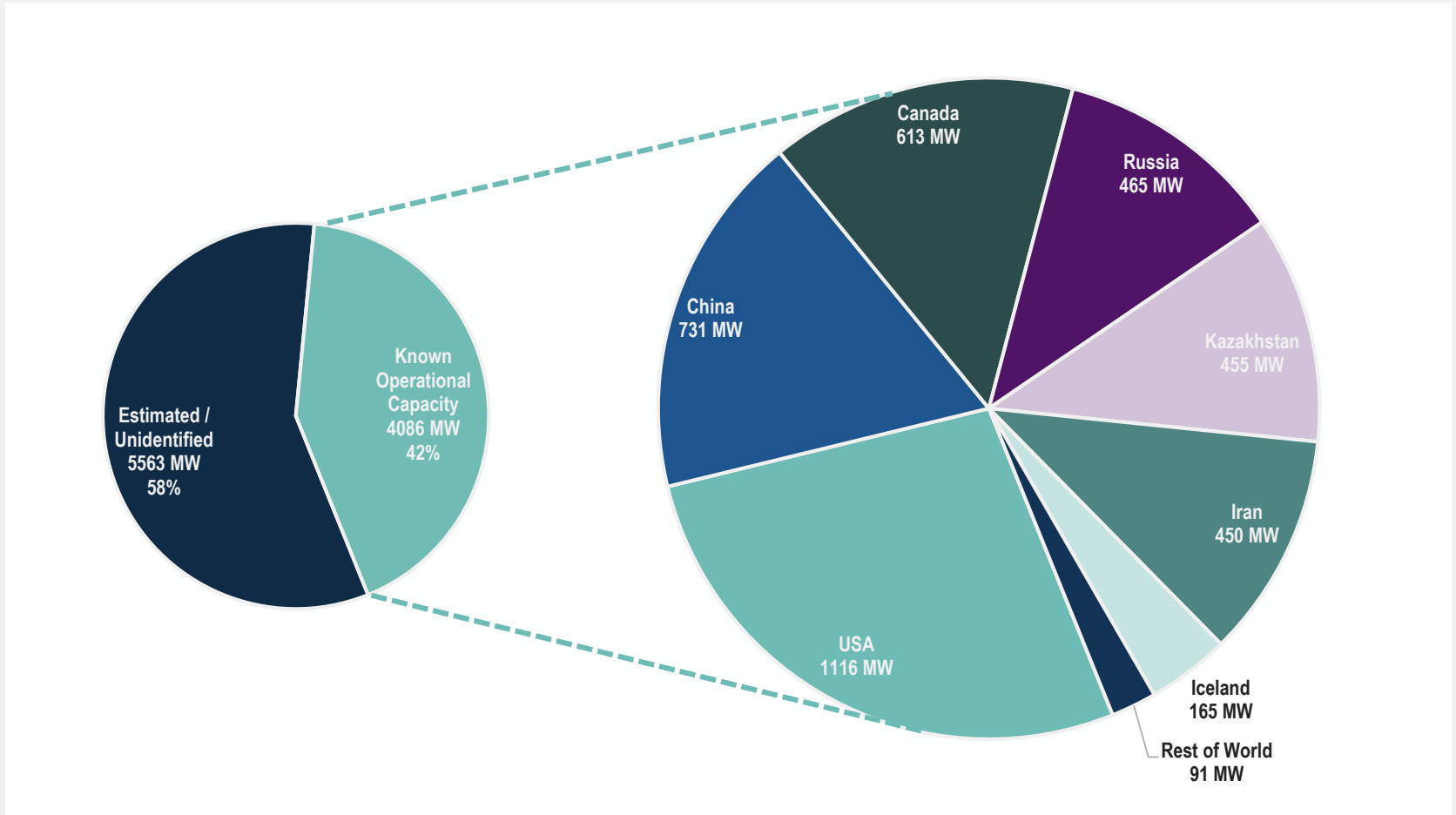**Known Capacity Distribution**

Estimated share of capacity identified by BitOoda

Implied Total Capacity Distribution

Known Capacity Distribution (pie chart):
- Canada 613 MW
- Russia 465 MW
- China 731 MW
- Kazakhstan 455 MW
- USA 1116 MW
- Iran 450 MW
- Rest of World 91 MW
- Iceland 165 MW

Estimated share of capacity identified by BitOoda (bar chart):
- USA 85.0%
- China 15.0%
- Canada 85.0%
- Russia 60.0%
- Kazakhstan 60.0%
- Iran 60.0%
- Iceland 90.0%
- Rest of World 33.2%

Applying "estimated known share" of total capacity to imply total country capacity

Implied Total Capacity Distribution (pie chart):
- China 4873 MW 50%
- Canada 721 MW 7%
- Russia 775 MW 8%
- Kazakhstan 758 MW 8%
- Iran 750 MW 8%
- Iceland 183 MW 2%
- Rest of World 274 MW 3%
- USA 1313 MW 14%

Figure: Geographic distribution of surveyed and estimated global mining capacity
Note: Some of the underlying data was shared under condition of anonymity
As of 7/14/2020

Source: BitOoda estimates, Miners, ASIC makers, Public sources

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Bitcoin Network
Cost Curve

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Power cost curve
BTC Mining Network

- We identified size and power costs for facilities representing roughly 31% of the estimated maximum power consumption of the Bitcoin network
- Extrapolating to the rest of the network, we think 50%+ of capacity is at under 3c/kWh power cost
- The confidence interval / outer bounds for sub-3c power is about 35% - 55%

Figure: Power cost curve: Mapping power cost vs. share of network capacity
As of 7/14/2020

Source: BitOoda estimates, Miners, ASIC makers, Public sources

Estimated 80% utilization
Within known power cost sources

- We believe low-cost miners are running near full capacity, while higher cost miners are operating at about 2/3 capacity, within the known 31% of identified capacity
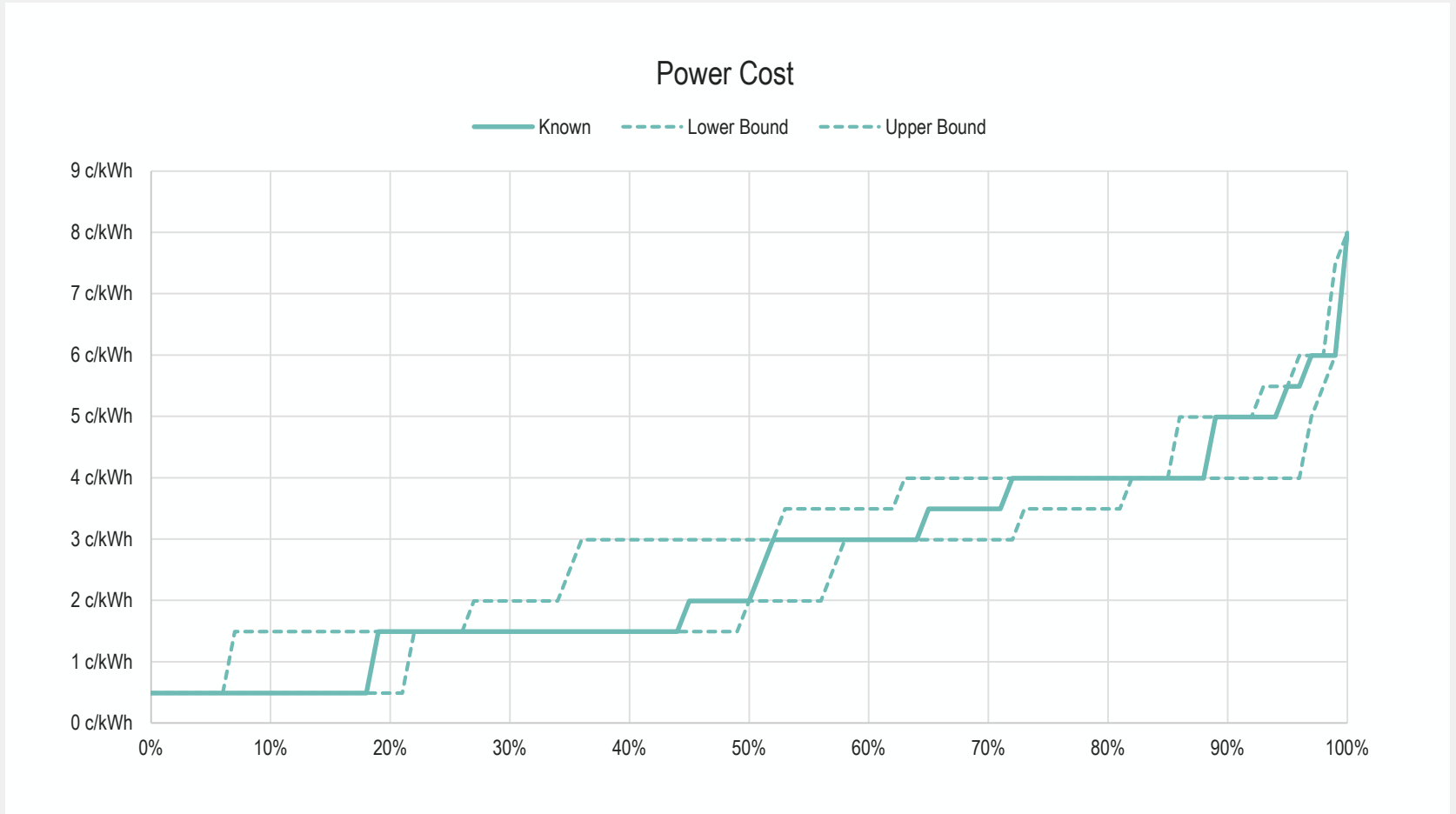- Utilization in sample may be higher than the broader industry, because our sample may have a more efficient rig mix vs. the general miner population
- Weighted average cost to mine 1 BTC ~$6500

Power Cost	Known Capacity	Share of Known Capacity	Total Capacity (if mix = known capacity mix)	Range of Total Capacity	Share of Total Capacity	Wt. Avg Cash Cost /BTC
Below 1c/kWh	450 MW	15.1%	1454 MW	450 - 1705MW	5.1%	$3,323
1c/kWh -2c/kWh	604	20.2	1951	1269 - 2092	6.9	$4,492
2c/kWh -3c/kWh	198	6.6	635	574 - 771	2.3	$5,250
3c/kWh -4c/kWh	733	24.5	2157	2299 - 2605	8.3	$6,961
4c/kWh -5c/kWh	600	20.1	1766	1797 - 2250	6.8	$8,256
5c/kWh -6c/kWh	280	9.4	858	804 - 960	3.2	$10,102
6c/kWh -7c/kWh	92	3.1	279	92 - 314	1.0	$11,437
Above 7c/kWh	30	1.0	-312	30 - 169	0.3	$13,823
Total	**2987 MW**	**100.0**	**8788 MW**		**34.0**	**$6,561**

Sampled power capacity: Available and Utilized

100.0% — 450 MW (0c/kWh -1c/kWh)
100.0% — 604 MW (1c/kWh -2c/kWh)
85.0% — 30 MW / 168 MW (2c/kWh -3c/kWh)
67.0% — 242 MW / 491 MW (3c/kWh -4c/kWh)
67.0% — 198 MW / 402 MW (4c/kWh -5c/kWh)
67.0% — 92 MW / 188 MW (5c/kWh -6c/kWh)
67.0% — 30 MW / 61 MW (6c/kWh -7c/kWh)
67.0% — 10 MW / 20 MW (Greater Than 7c/kWh)
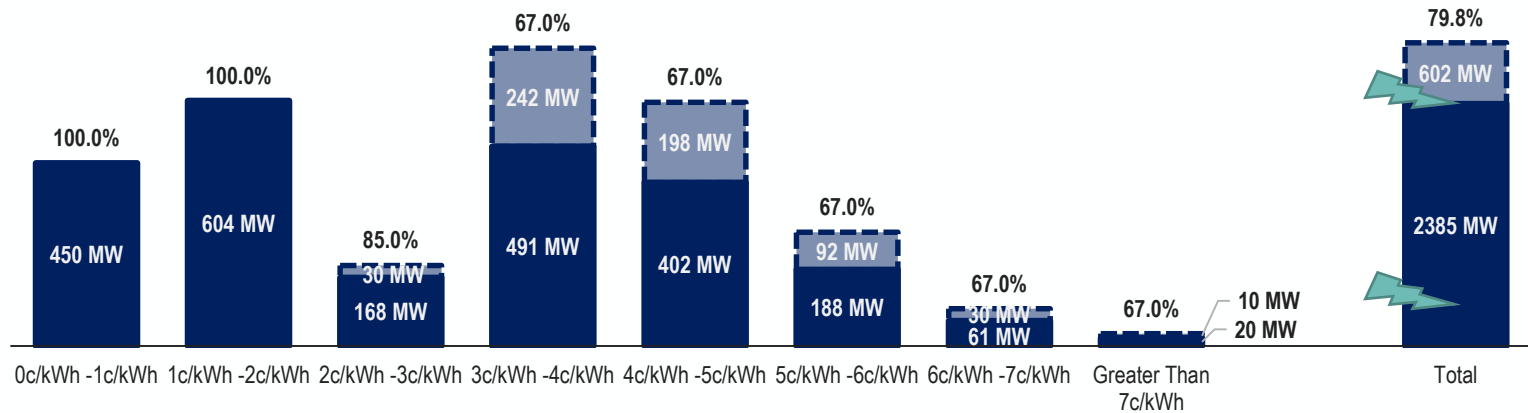79.8% — 602 MW / 2385 MW (Total)

Figure: Capacity / utilization cost for sampled miners and estimated network power capacity
As of 7/14/2020

Source: BitOoda estimates, Miners, ASIC makers, Public sources

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3-4c/kWh Modal Power Cost : Capacity at different price points

- We extrapolated power capacity at different price points for the 9.6GW of estimated total Bitcoin mining capacity based on the known prices for the 3GW of capacity in our research sample
- We estimate upper / lower / mid bounds of capacity based on whether the mix of unknown 69% of power capacity is at a lower or higher price vs. the known capacity

Legend:
- Upper Bound
- "Likely" Estimate
- Lower Bound

0c/kWh -1c/kWh
- 1705 MW
- 1454 MW
- 450 MW

1c/kWh -2c/kWh
- 2313 MW
- 1951 MW
- 1819 MW

2c/kWh -3c/kWh
- 784 MW
- 644 MW
- 574 MW

3c/kWh -4c/kWh
- 2771 MW
- 2369 MW
- 2299 MW
- **Modal power cost**

4c/kWh -5c/kWh
- 2250 MW
- 1939 MW
- 1797 MW

5c/kWh -6c/kWh
- 1001 MW
- 884 MW
- 804 MW

6c/kWh -7c/kWh
- 347 MW
- 279 MW
- 128 MW

Greater Than 7c/kWh
- 169 MW
- 130 MW
- 30 MW

Migratory capacity during Hydro season affects the width of this band
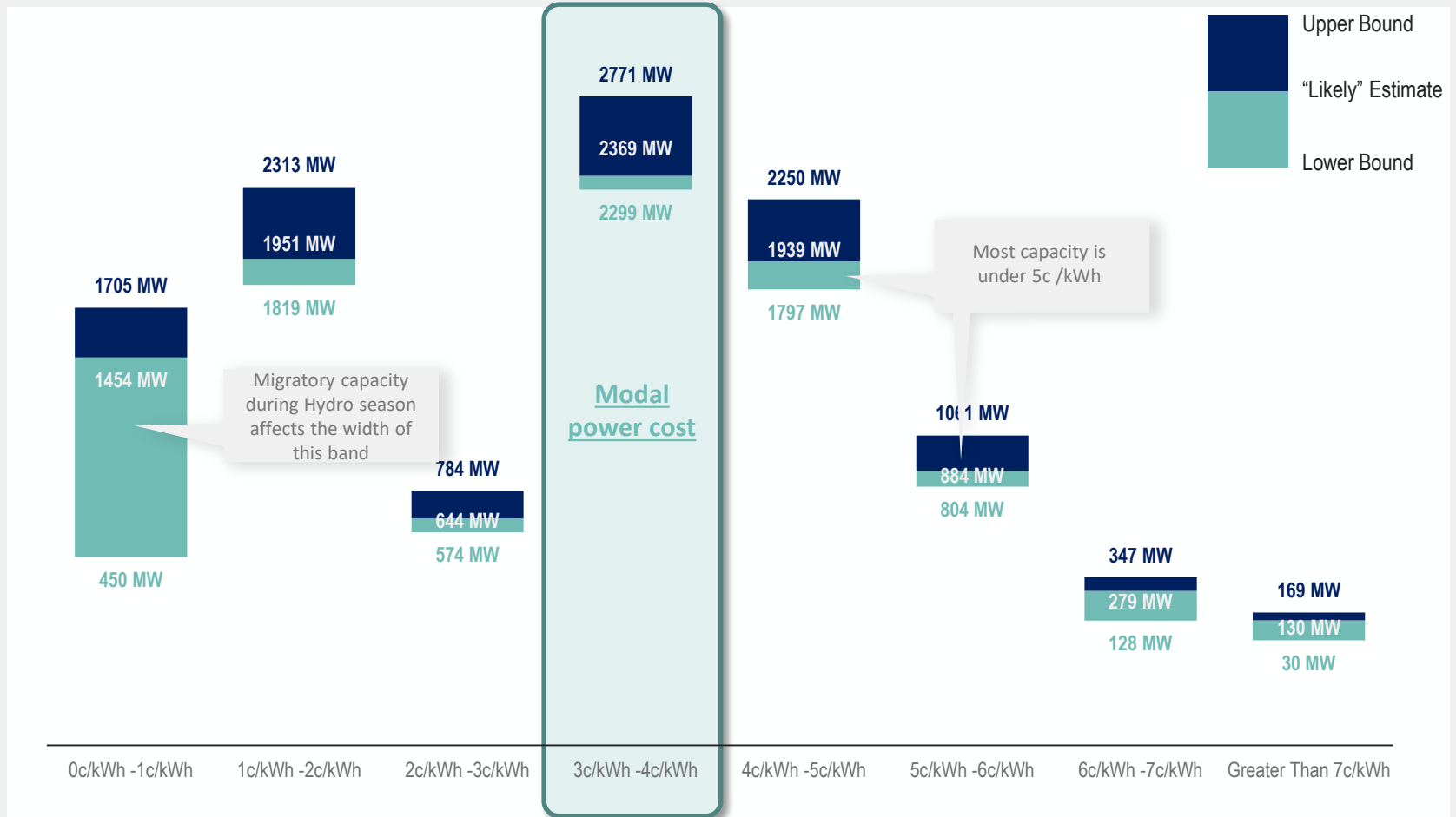
Most capacity is under 5c /kWh

Figure: Power distribution: Lower, median and upper bounds of capacity at each power price point As of 7/14/2020

Source: BitOoda estimates, Miners, ASIC makers, Public sources

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Cash cost to mine 1 BTC

- Based on our cost curve estimates, the median cash expense to mine 1 BTC is ~$5000
- We assess the upper confidence interval on median cost is ~$6000, assuming the unknown power sources have a higher power cost mix than our known data

Cost / BTC

—— Known Data   ----- Upper Bound   ----- Lower Bound

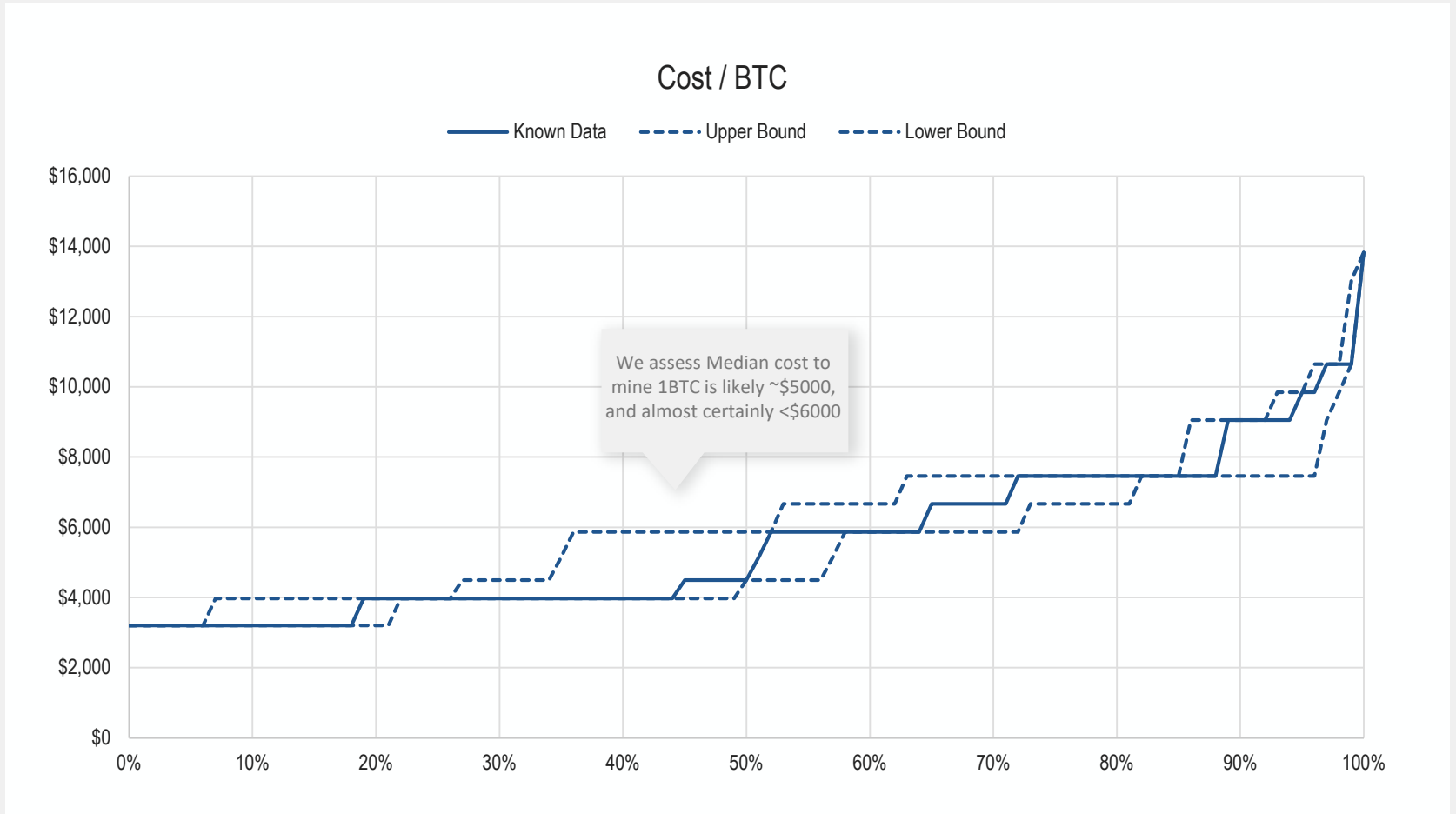We assess Median cost to mine 1BTC is likely ~$5000, and almost certainly <$6000

Figure: Cost to mine 1 BTC, based on network capacity at different power costs
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Miners, ASIC makers, Public sources

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Daily Revs vs Cost per PH/s:
Need sub-2c / kWh to run S9s

- The columns in the chart below show the daily operating cost to run each device class, in 1c / kWh power cost increments
- The lines show the dollar value of Bitcoin mined per PH/s per day at current prices, and if BTC were $11000 or $13000
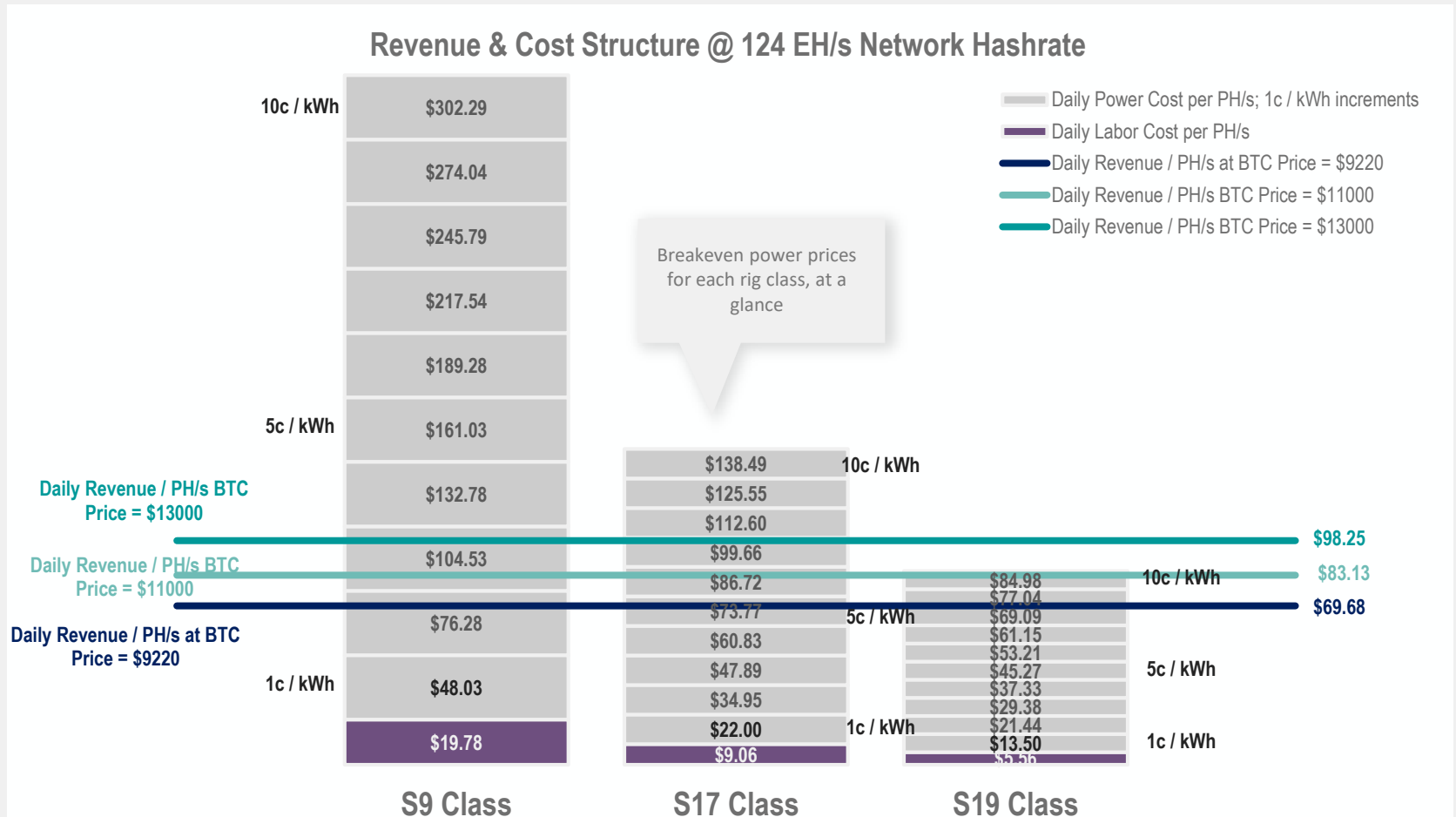- S9 class rigs need sub-2c / kWh power to be viable, but S17 class is viable up to 6c / kWh; S19 class up to 8c / kWh

Revenue & Cost Structure @ 124 EH/s Network Hashrate

Legend:
- Daily Power Cost per PH/s; 1c / kWh increments
- Daily Labor Cost per PH/s
- Daily Revenue / PH/s at BTC Price = $9220
- Daily Revenue / PH/s BTC Price = $11000
- Daily Revenue / PH/s BTC Price = $13000

Breakeven power prices for each rig class, at a glance

S9 Class (1c/kWh to 10c/kWh):
- 10c / kWh — $302.29
- $274.04
- $245.79
- $217.54
- $189.28
- 5c / kWh — $161.03
- $132.78
- $104.53
- $76.28
- 1c / kWh — $48.03
- $19.78 (Labor)

S17 Class:
- 10c / kWh — $138.49
- $125.55
- $112.60
- $99.66
- $86.72
- 5c / kWh — $73.77
- $60.83
- $47.89
- $34.95
- 1c / kWh — $22.00
- $9.06 (Labor)

S19 Class:
- 10c / kWh — $84.98
- $77.04
- $69.09
- $61.15
- $53.21
- 5c / kWh — $45.27
- $37.33
- $29.38
- $21.44
- 1c / kWh — $13.50

Revenue lines:
- Daily Revenue / PH/s BTC Price = $13000 → $98.25
- Daily Revenue / PH/s BTC Price = $11000 → $83.13
- Daily Revenue / PH/s at BTC Price = $9220 → $69.68

Figure: Daily revenue and cash operating costs using different rigs at different power price, at _current Hashrate._
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Power Costs:
Effects of China's Hydro Season

BitOoda

Hydro Season =
Lower Power Cost

- China accounts for as much as 65% of global Hashrate per Cambridge Center for Alternative Finance; our estimates are somewhat lower at about 50%
- Much of this computing power operates at 2.5-3c / kWh in Inner Mongolia during the dry season
- During flood season, these miners migrate significant capacity to Sichuan and Yunnan provinces to take advantage of as low as sub- 1c/kWh power
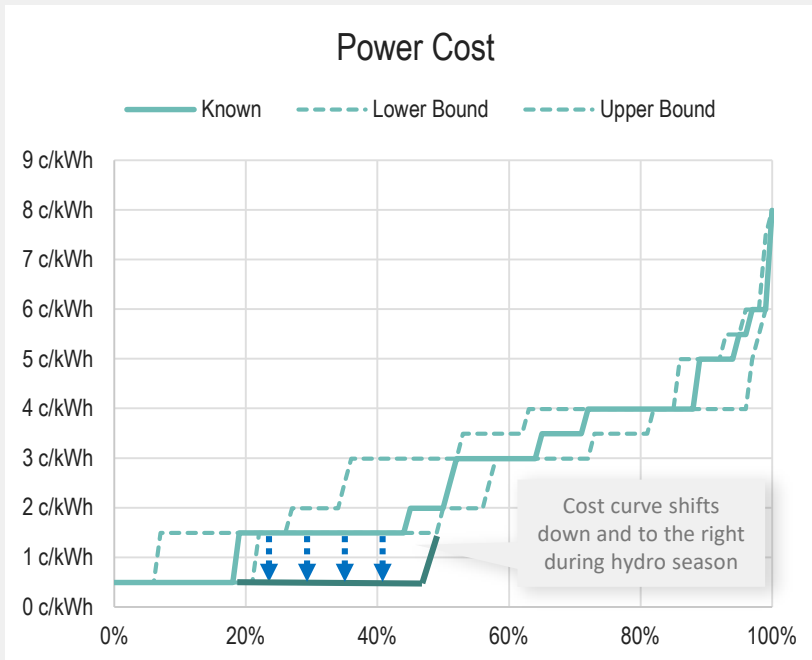
Power Cost

Known — Lower Bound — Upper Bound

9 c/kWh
8 c/kWh
7 c/kWh
6 c/kWh
5 c/kWh
4 c/kWh
3 c/kWh
2 c/kWh
1 c/kWh
0 c/kWh

0%   20%   40%   60%   80%   100%

Cost curve shifts down and to the right during hydro season

Figure: Power cost curve shifts during China's flood season

Source: BitOoda estimates, Miners, ASIC makers, Public sources

- **An S9 rig generates $28 / MWh in revenue, which means that it could be profitable to mine Bitcoin using older generation, depreciated rigs.**

- **Furthermore, even with newer equipment, dropping the price of electricity from $25-30 to $10 / MWh increases profitability meaningfully.**

- **Assuming an additional $7 / MWh as labor / overhead – which may be high in the Chinese context – the cash contribution for an S17 class rig would double from $21 to $41.**

- **For a sample 50MW facility running S17 class equipment, this is $4.4 million in incremental cash flow to fund rig upgrades and capacity expansion, to a total of $8.8 million.**

- **This would allow the S17 class miner to buy over 3500 next gen S19 class rigs, or upgrade / expand 12MW of their capacity.**

- **We think the upper end of the cost curve is unaffected: 4c+ / kWh power is less migratory.**

BitOoda

Hydro Season enhances capital accumulation, supporting BTC Price Appreciation

- Lower costs = lower consistent selling pressure

Average (Since 2014 Dry Season)	Dry	Flood
Price Change	33%	75%
Hashrate Change	82%	81%

- During Hydro season, Chinese miners are accumulating capital for reinvestment.

- In the prior example, BTC price / network Hashrate being equal, the hypothetical 50MW miner would have to sell $8M in BTC during the dry season to meet operating expenses, but just $3.7M during the flood season.

- Across multiple GW of migratory power capacity in China, that is about $1+ billion of incremental BTC accumulated and transferred "off exchange" between miners and rig manufacturers who accept payment in crypto currency.

- Miners pay for their rigs several months in advance to secure shipment of rigs from suppliers like Bitmain, Canaan or MicroBT. The suppliers in turn make advance payments for wafer capacity at foundries such as TSMC, with a typical 12-13 week lead time.

- While this BTC does get eventually sold to the market to pay TSMC and other semiconductor foundries in fiat, we believe the discretionary timing of this sale allows for more favorable trading strategies.

- Absent similar seasonality in fiat flows buying into crypto and BTC in particular, there is consistent fiat flow seeking to absorb less BTC flow during hydro season. Also, there is a feedback loop where fiat flows increase following BTC price appreciation.

- In our view, this dynamic supports the pattern of higher price appreciation for Bitcoin during the Chinese flood season.

BitOoda

Hydro Season ≠ Hashrate Growth

- Average Hashrate growth is consistent between Flood and Dry seasons
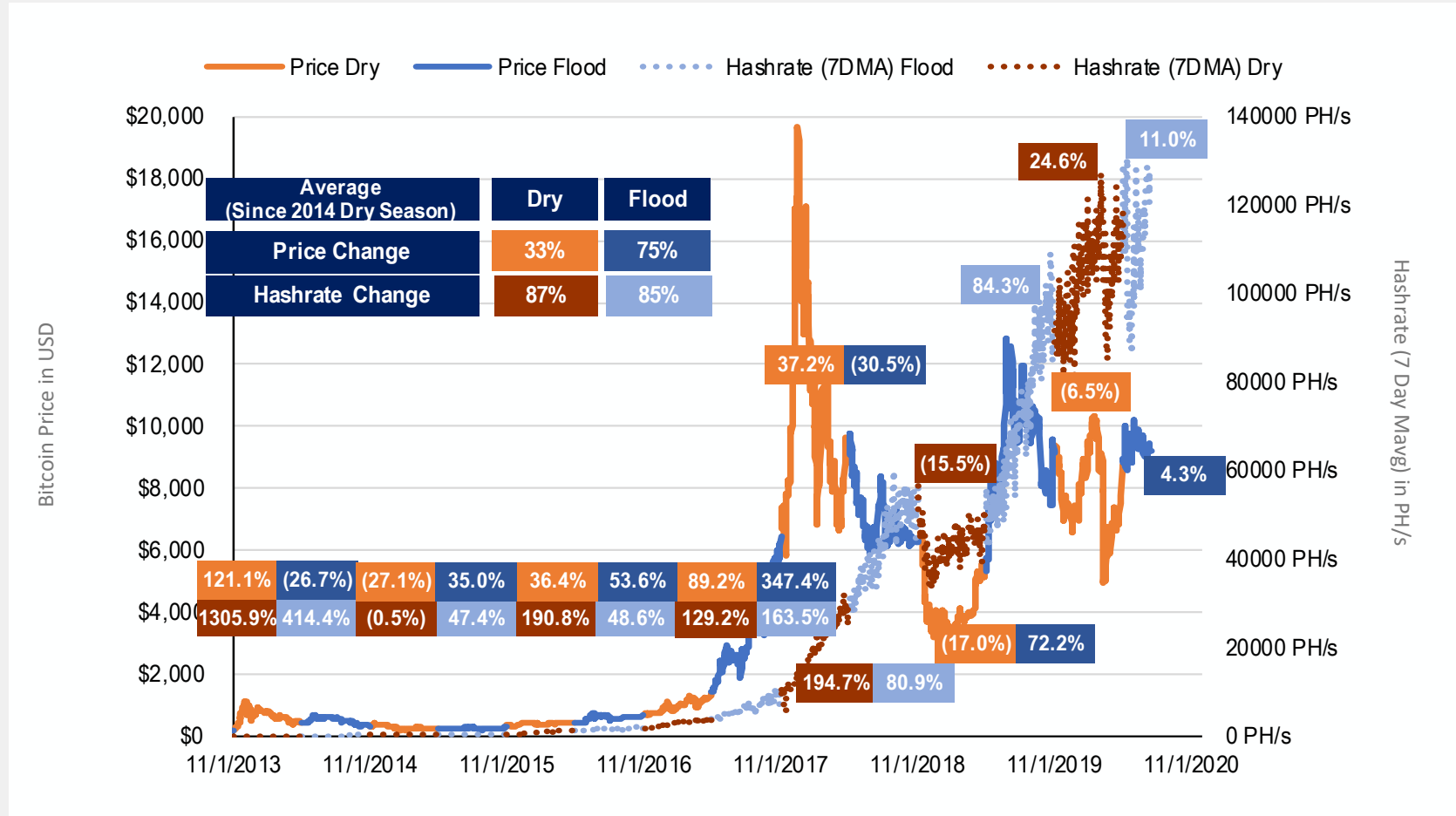- But over 6 years price appreciation appears higher during Flood seasons

Average (Since 2014 Dry Season)	Dry	Flood
Price Change	33%	75%
Hashrate Change	87%	85%

Figure: Hashrate and BTC price segregated by flood and dry seasons
Note: Since 2014; averages exclude Nov 2013-Oct 2014
As of 7/14/2020

Source: BitOoda, Blockchain.com, Coinmetrics

Price changes lead
Hashrate change

- We examined the correlation between trailing price growth and Hashrate growth over periods ranging from 15 days to 1 year
- Highest correlation region shows that **price appreciation** over several months **drives Hashrate growth**, with a 4-6 month lag
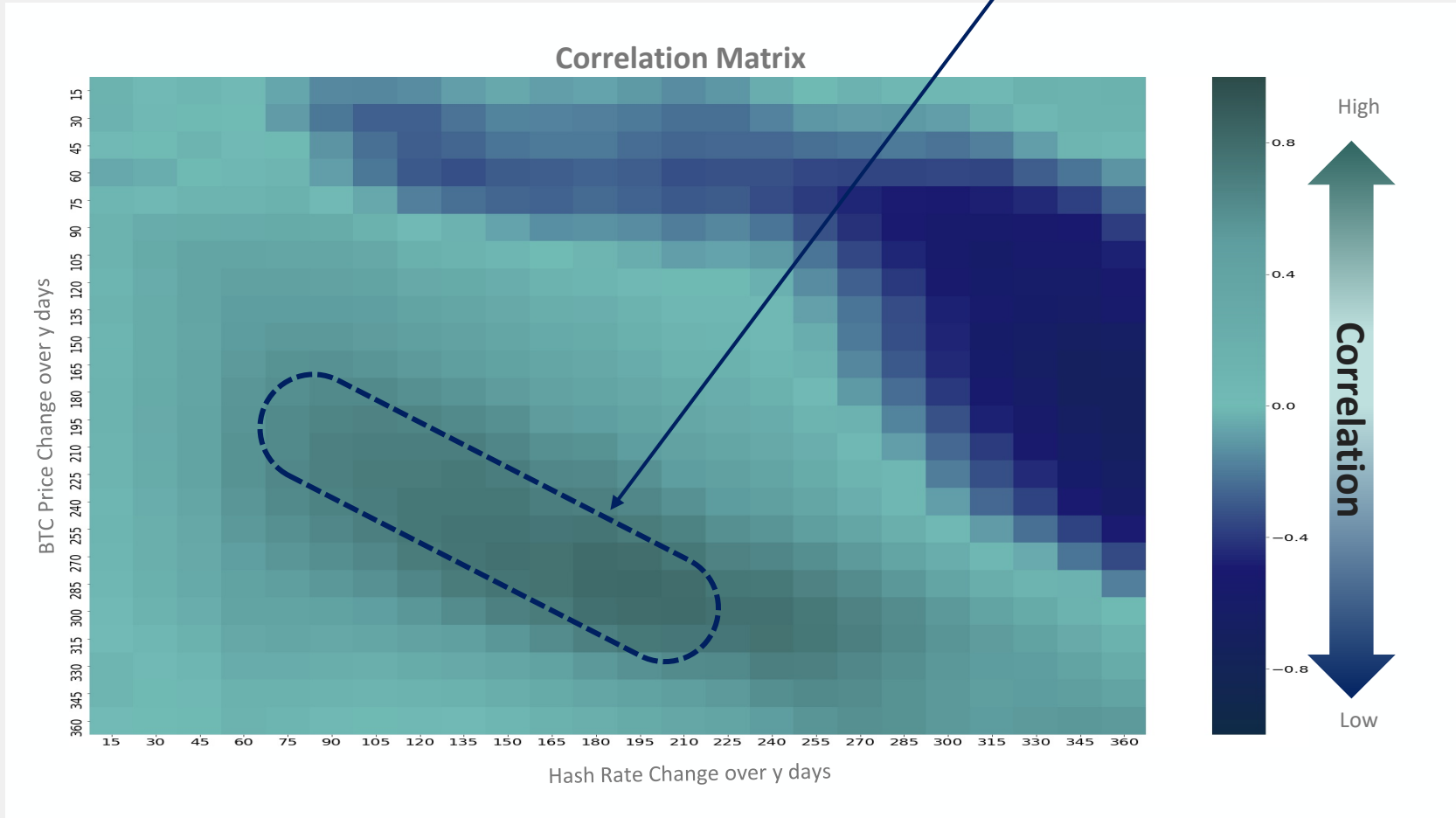

Figure: Correlation between price changes and Hashrate changes
Note: Past 12 months
As of 7/14/2020

Source:BitOoda, Blockchain.com,Kaiko, Coinmetrics

Bitcoin Network
Future Outlook

BitOoda

260+ EH/s Hashrate
Potential by June 2021

- At 10% growth in power capacity, the industry could draw 10.6 GW in 1 year
- This is based on a combination of miners' expansion plans, discounted since not every planned expansion will come to fruition, and potential shutdown of higher-priced power capacity
- We believe new devices will be a mix of S17 and, mostly, S19 class
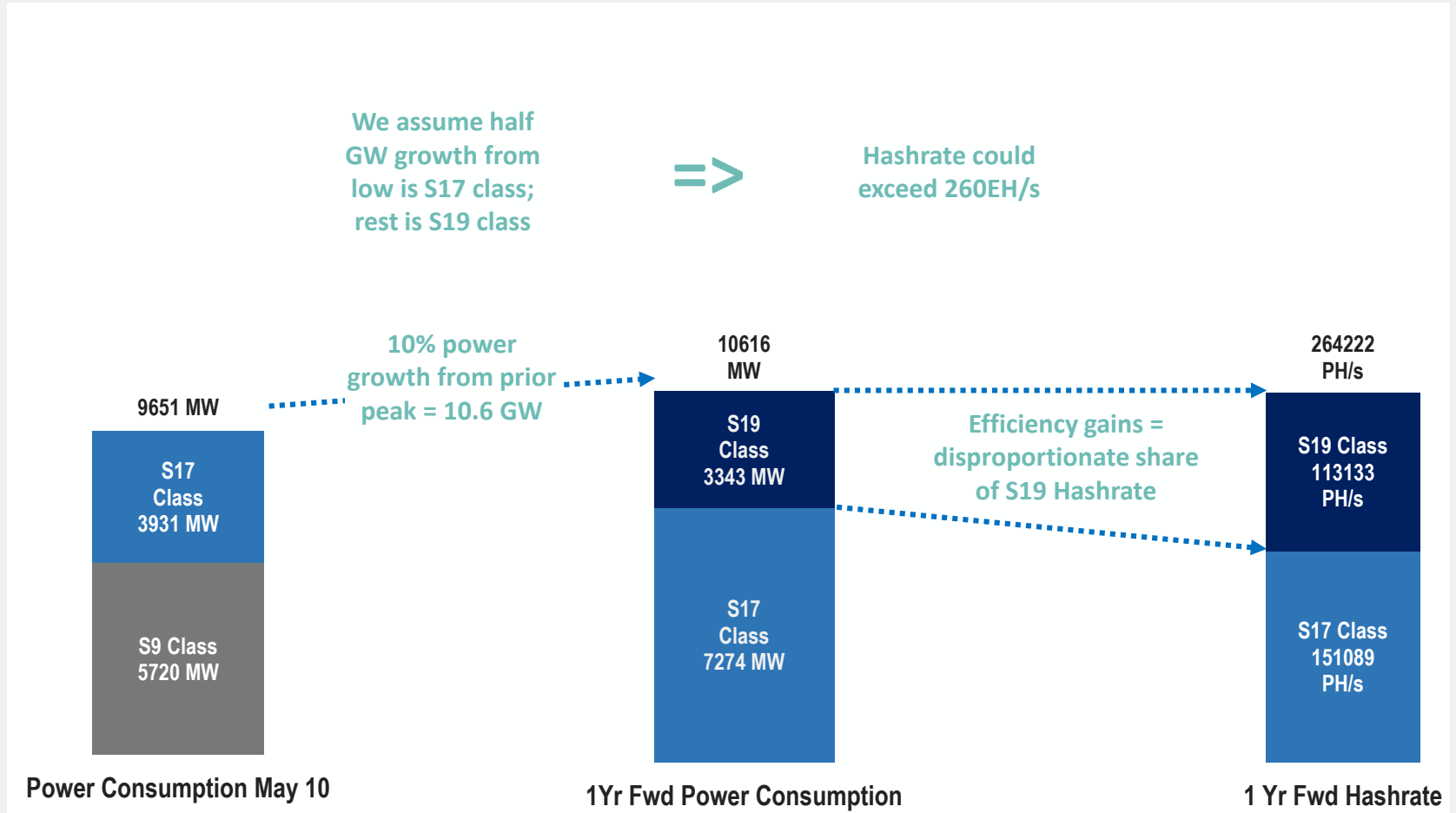- **Hashrate could exceed 260 EH/s in 1 year**

We assume half GW growth from low is S17 class; rest is S19 class

=>

Hashrate could exceed 260EH/s

10% power growth from prior peak = 10.6 GW

10616 MW

264222 PH/s

9651 MW

Efficiency gains = disproportionate share of S19 Hashrate

S17 Class 3931 MW

S9 Class 5720 MW

S19 Class 3343 MW

S17 Class 7274 MW

S19 Class 113133 PH/s

S17 Class 151089 PH/s

Power Consumption May 10

1Yr Fwd Power Consumption

1 Yr Fwd Hashrate

Figure: Bitcoin Hashrate and power consumption
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

~10.6GW power capacity
Fully utilized by mid 2021

- We believe a negligible quantity of S9 class rigs will remain in operation after November 2020, barring a large surge in Bitcoin price
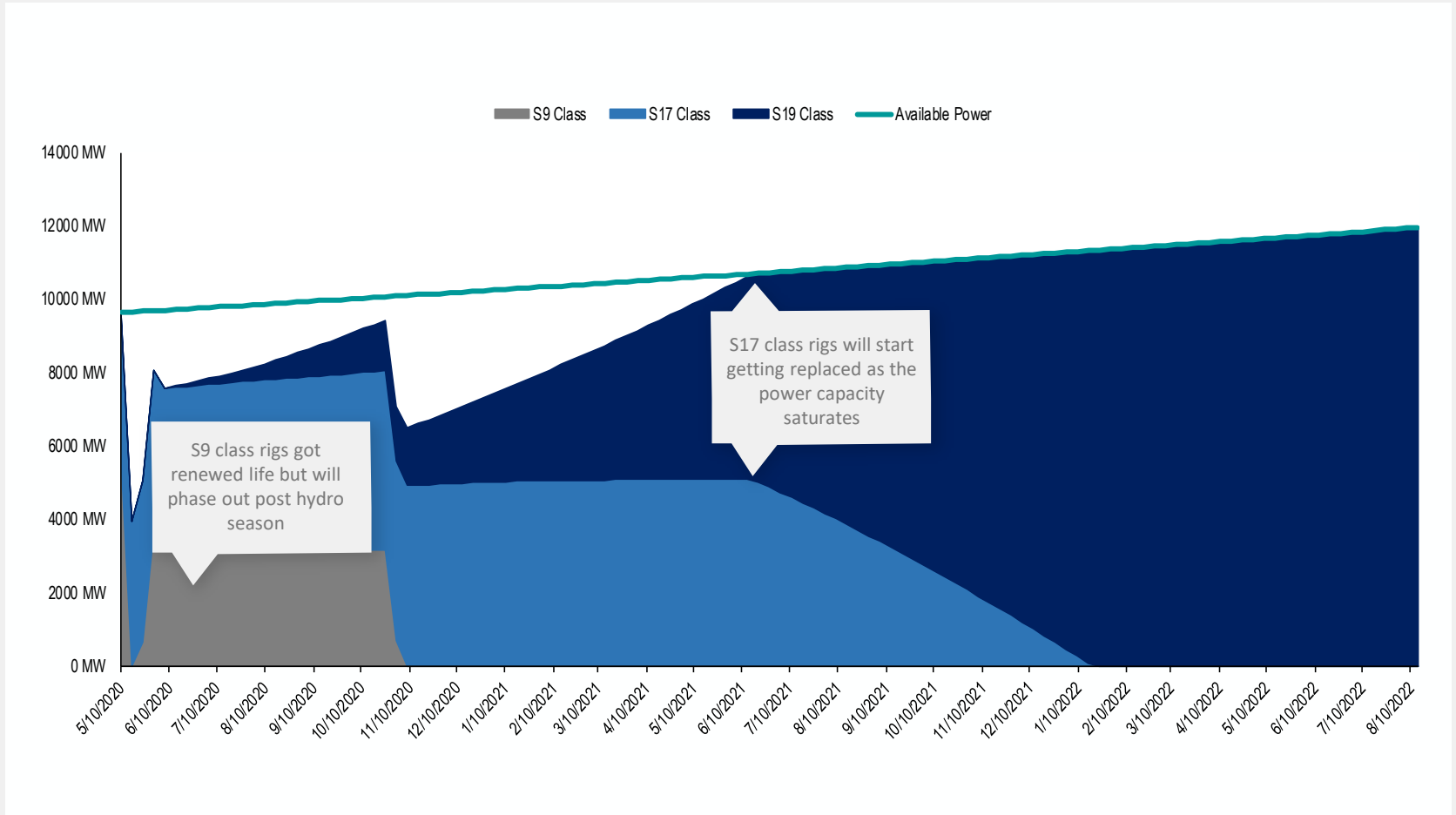- While some S17 class shipments will continue, a growing share of new rigs will be S19 class

Figure: Bitcoin power consumption by device class
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

Hashrate 260 EH/s in 1 yr
Driven by upgrade cycle

- The upgrade cycle should drive Hashrate to 260 EH/s in 1 year, and to 360EH/s in 2 years
- Power capacity is the boundary condition: upside to this number could expand Hashrate faster
- Near term, shipment delays from China, and especially delays from Bitmain, could pose a downside to our base-case hash estimates
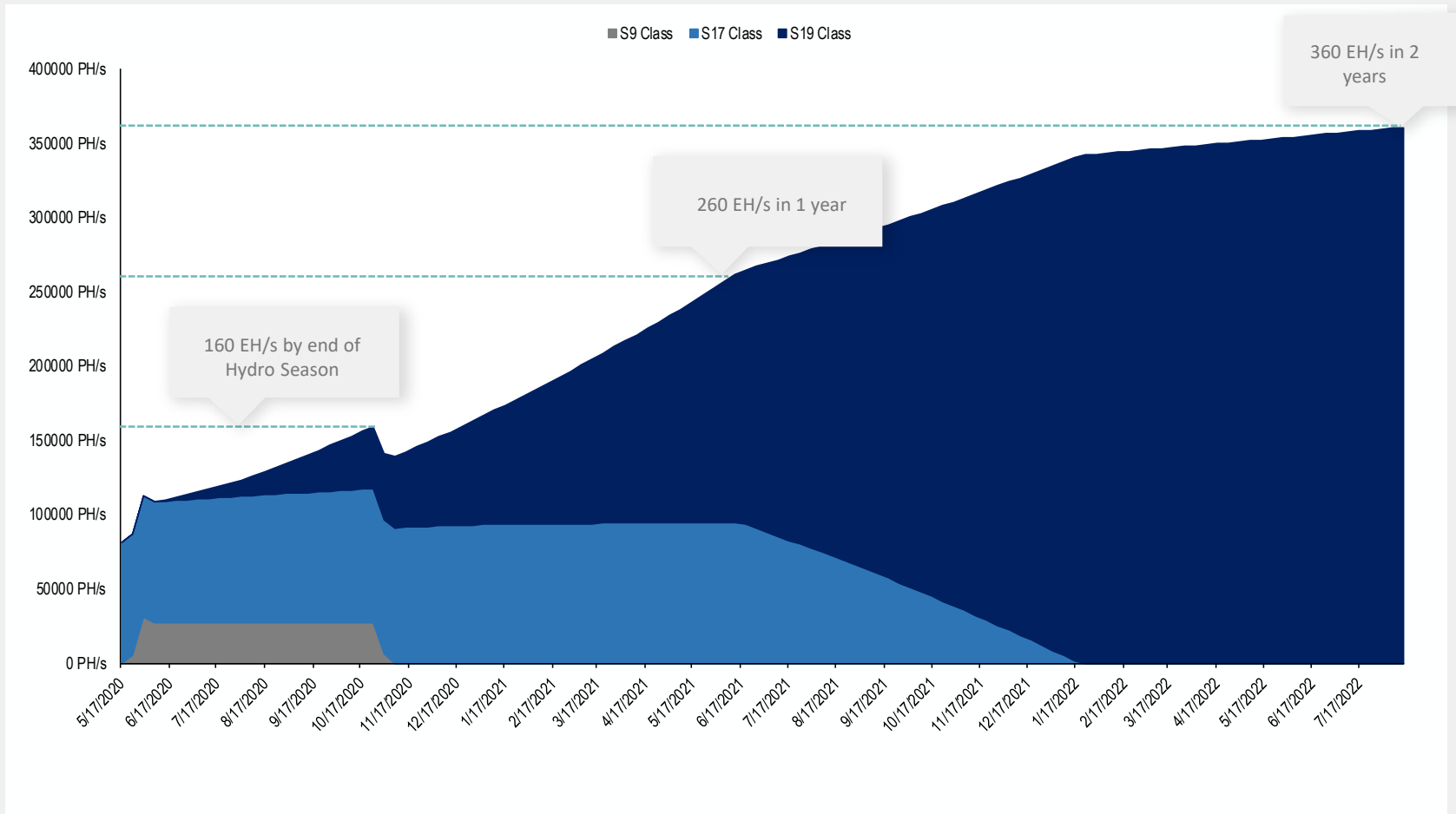

360 EH/s in 2 years

260 EH/s in 1 year

160 EH/s by end of Hydro Season

Legend: ■ S9 Class ■ S17 Class ■ S19 Class

Figure: Bitcoin Hashrate by device class
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Hashrate growth rates
will likely moderate...

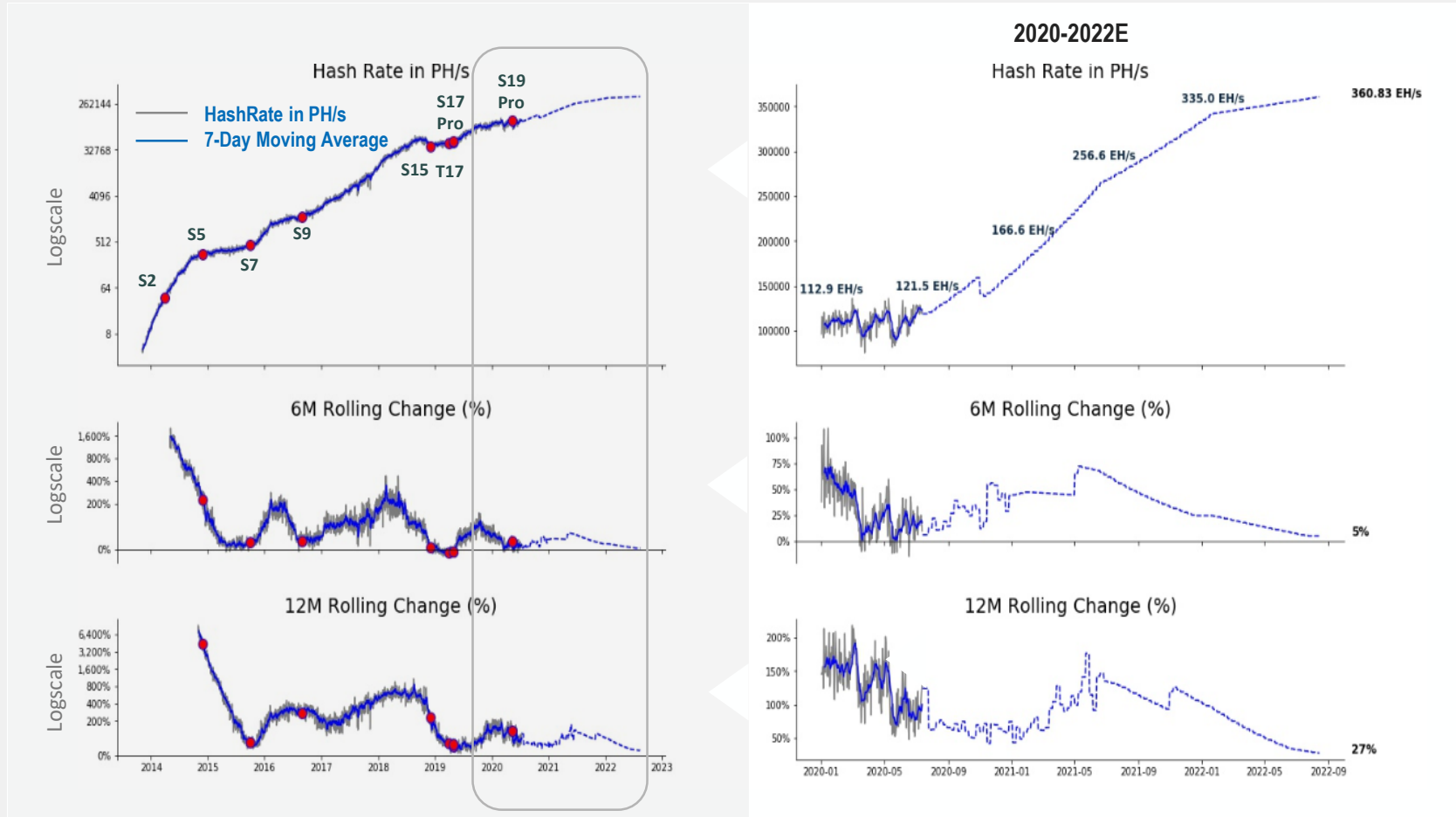Despite Hashrate rising to 360EH/s, we think growth will begin to moderate in 2022

Figure: Bitcoin Hashrate and rolling changes
Note: Since 2014 ; data as of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Difficulty could more than
triple in 24 months

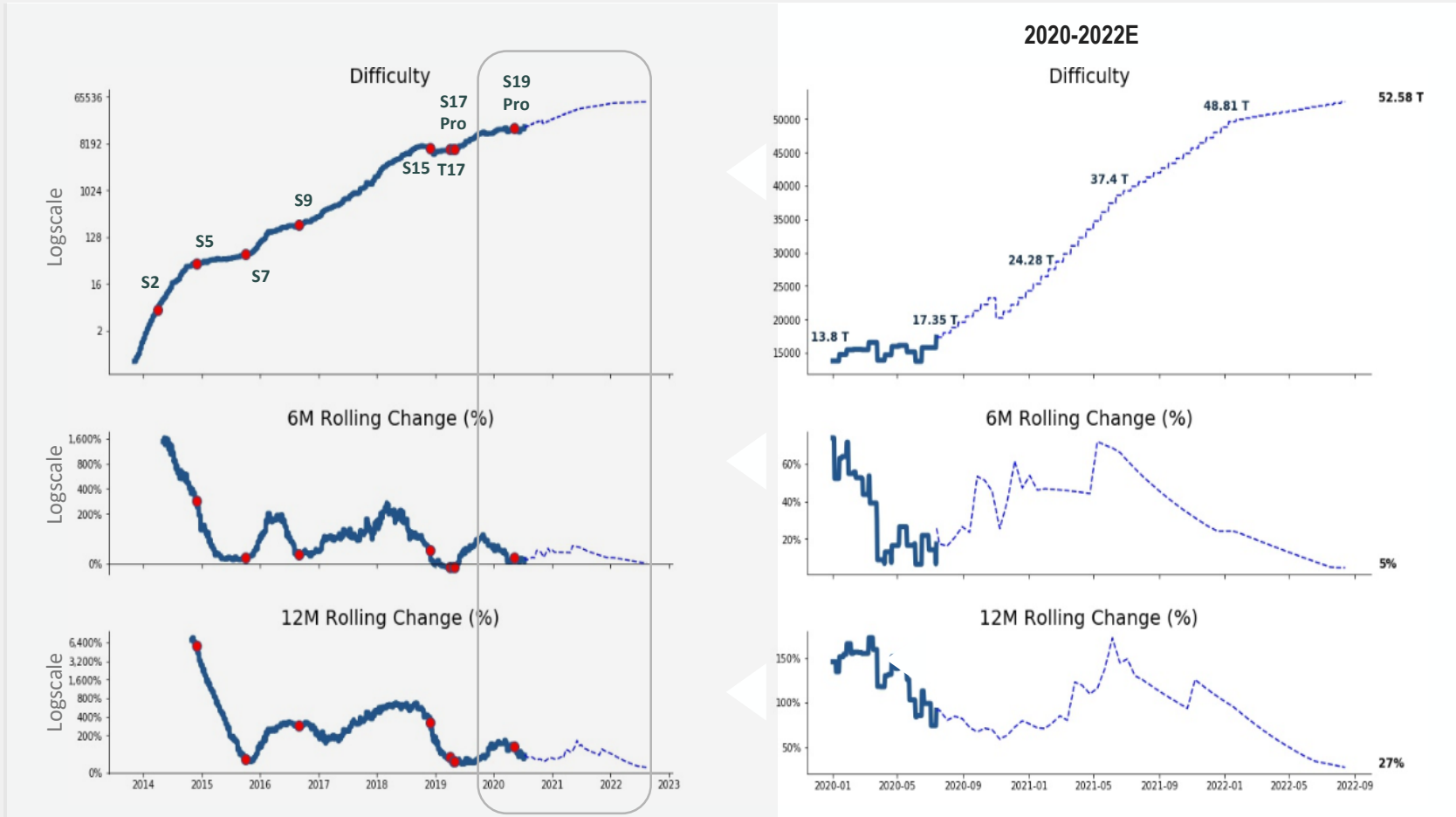Increasing Hashrate could drive difficulty monotonically higher

Figure: Bitcoin Difficulty and rolling changes
Note: Since 2014; data as of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Difficulty growth
moderates but continues…

Difficulty changes are a reflection of changing Hashrate, led by rig upgrades, available power capacity growth and, occasionally, by price declines driving shut-ins of older rigs or higher power cost facilities
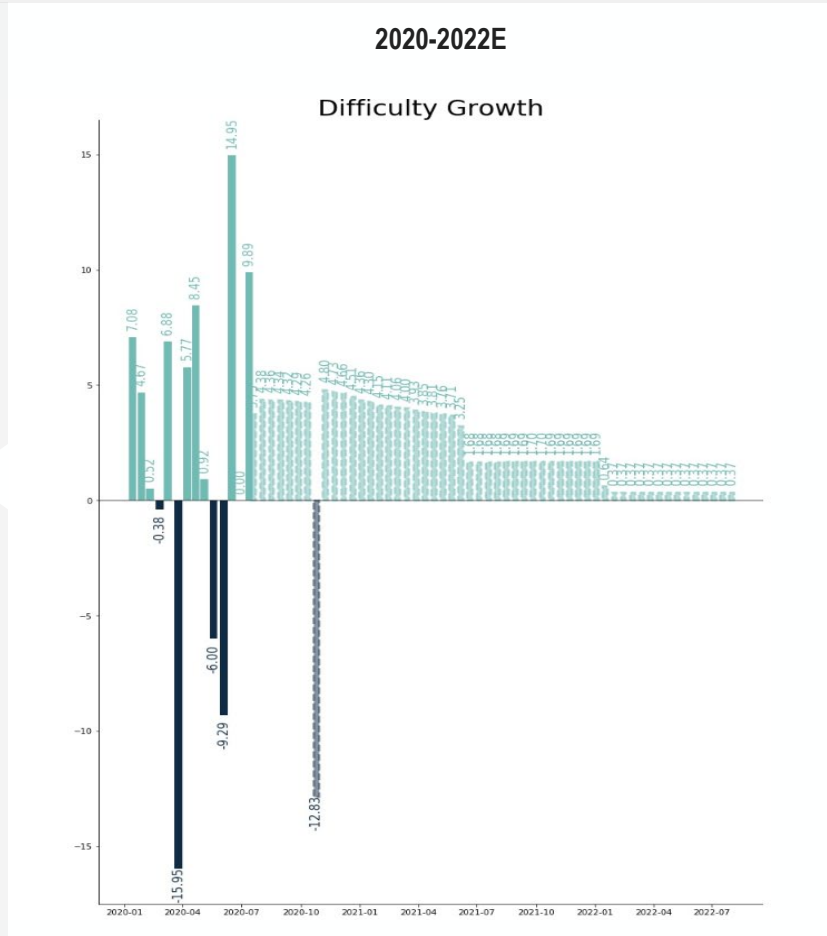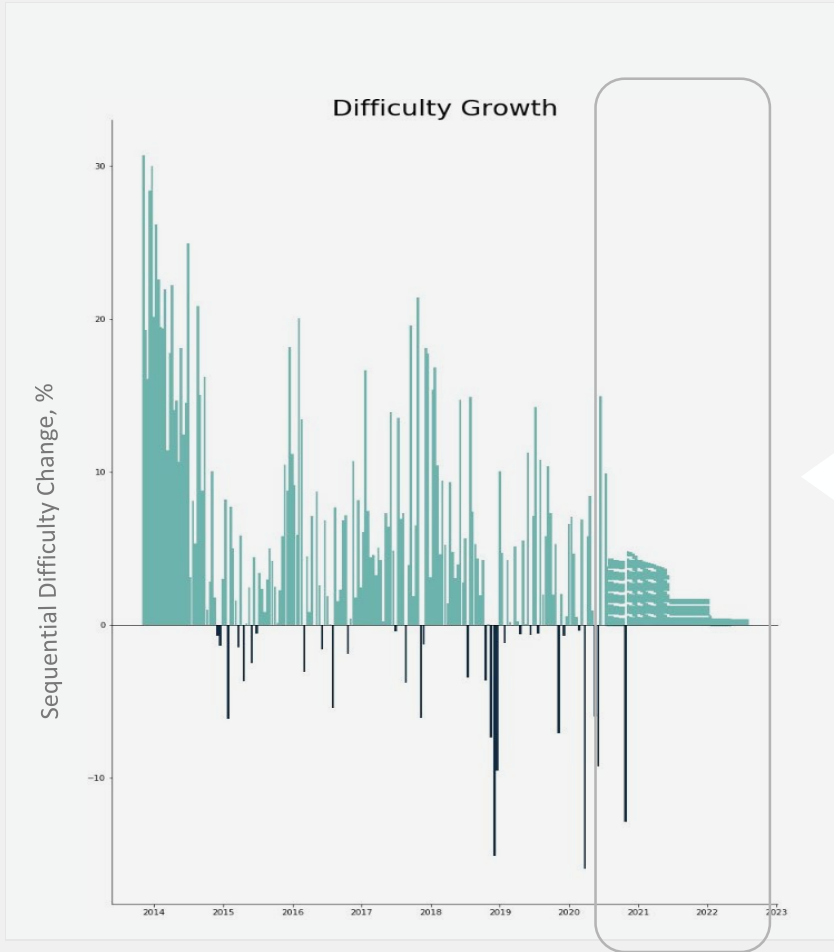

2020-2022E

Difficulty Growth

Figure: Bitcoin difficulty reset history
Note: Since Nov 2013, sequential epoch change, %; data as of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Hashrate ↑ = less BTC/PH/s:
Weakening economics

- As Hashrate rises, 1 PH/s earns a falling share of daily revenue
- Thus, at flat BTC prices, profitability erodes, and an increasing proportion of mining capacity – both older rigs and entire facilities – become unviable
- At 260EH/s, mining at $19,500 BTC price is about as profitable as at <$9220 today; at 360EH/s, price would need to be $27,000 to match today's profitability (see slide 20)

In one year…

200 EH/s Network Hashrate

| $302.29 |
| $274.04 |
| $245.79 |
| $217.54 |
| $189.28 |
| $161.03 |
| $132.78 |

$138.49
$125.55
$112.60
$104.53
$99.66
$86.72
$84.98
$77.04
$73.77
$69.09
$76.28
$61.15
$53.21
$60.83
$48.03
$47.89
$45.27
$37.33
$34.95
$29.38
$22.00
$21.44
$19.78
$13.50
$9.06

$74.9 @BTC Price = $16000
$60.8 @BTC Price = $13000
$46.8 @BTC Price = $10000

Sub 0.5c power needed for S9s at ~flat BTC price

S9 Class S17 Class S19 Class

260 EH/s Network Hashrate

| $302.29 |
| $274.04 |
| $245.79 |
| $217.54 |
| $189.28 |
| $161.03 |
| $132.78 |
| $104.53 |
| $76.28 |
| $48.03 |
| $19.78 |

$138.49
$125.55
$112.60
$99.66
$86.72
$84.98
$77.04
$73.77
$69.09
$61.15
$55.21
$60.83
$47.89
$45.27
$37.33
$34.95
$29.38
$22.00
$21.44
$13.50
$9.06

Breakeven power prices could degrade meaningfully with rising hash

$70.20 @BTC Price = $19500
$50.40 @BTC Price = $14000
$36.00 @BTC Price = $10000

S9 Class S17 Class S19 Class

360 EH/s Network Hashrate

| $302.29 |
| $274.04 |
| $245.79 |
| $217.54 |
| $189.28 |
| $161.03 |
| $132.78 |
| $104.53 |
| $76.28 |
| $48.03 |
| $19.78 |

$138.49
$125.55
$112.60
$99.66
$86.72
$84.98
$77.04
$73.77
$69.09
$61.15
$53.21
$60.83
$47.89
$45.27
$37.33
$34.95
$29.38
$22.00
$21.44
$13.50
$9.06

$70.2 @BTC Price = $27000
$46.8 @BTC Price = $18000
$26.0 @BTC Price = $10000

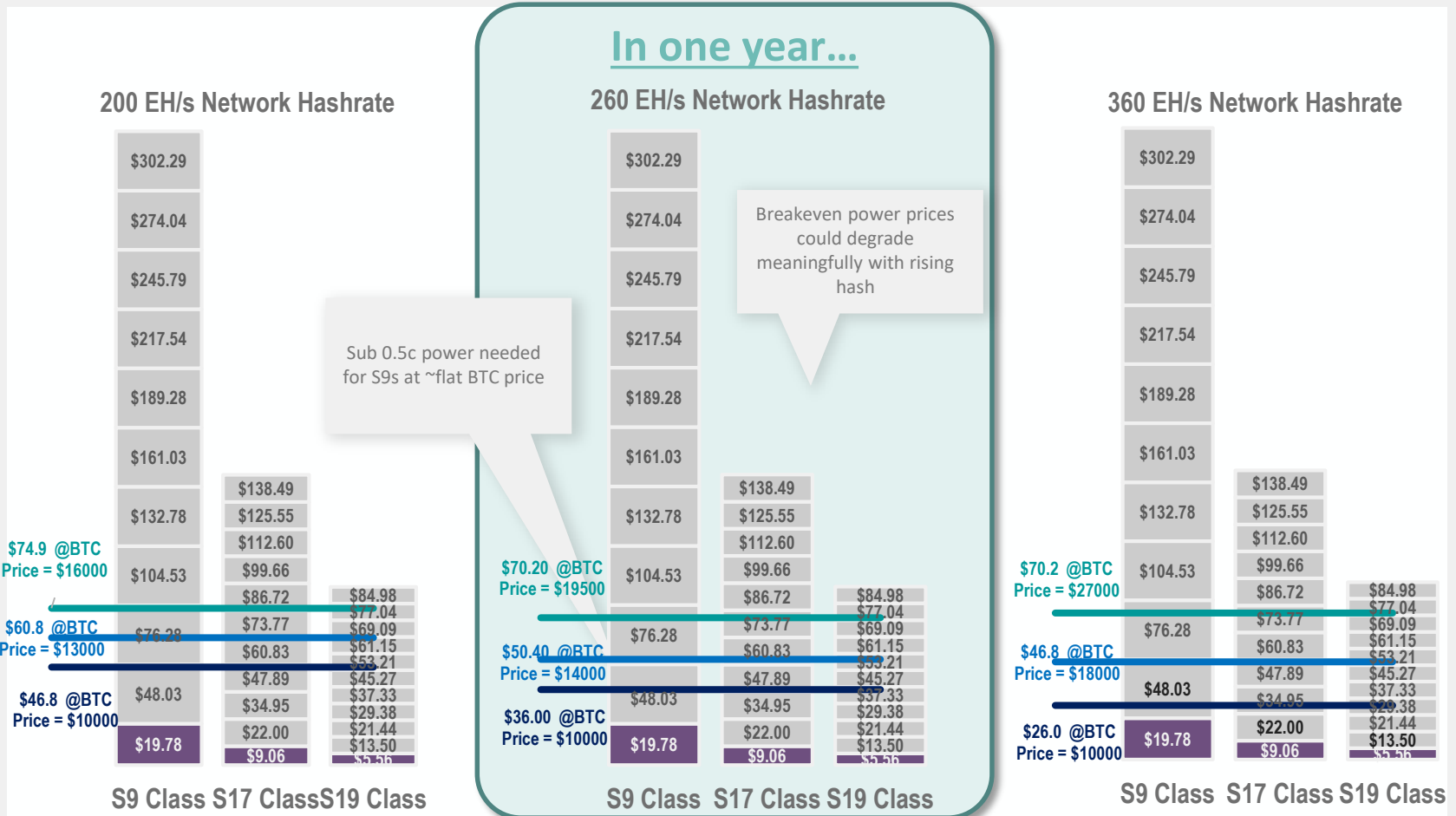**S9 Class S17 Class S19 Class**

Figure: Daily revenue and cash operating costs using different rigs at different power price, at _several FUTURE Hashrates._
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

BTC Flow per PH/s falls
as Hashrate increases

- As shown on previous slide, higher network Hashrate drives weaker economics
- Any offsetting price increase assumptions loom large in the viability of new capex projects
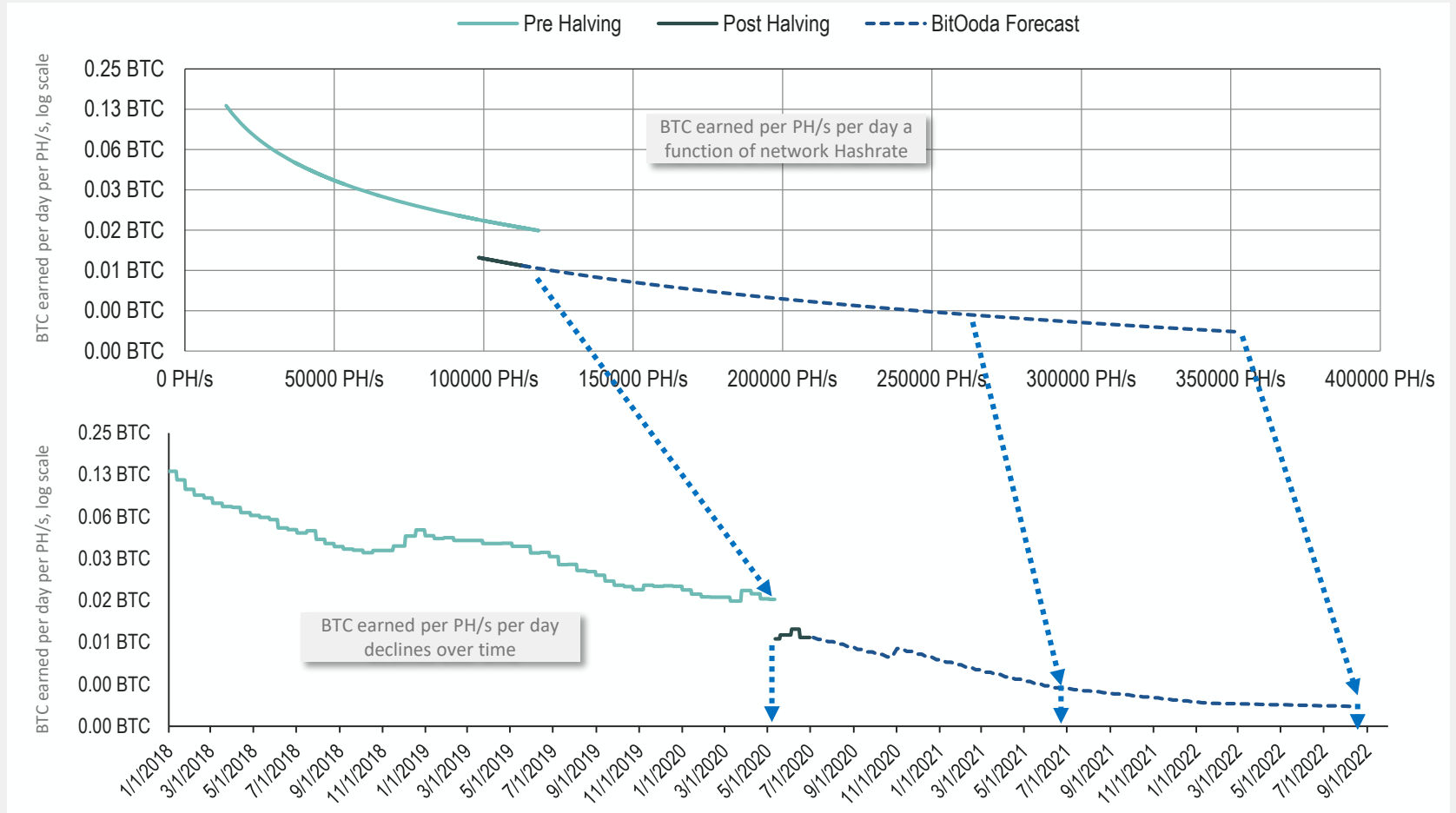

BTC earned per PH/s per day a function of network Hashrate

BTC earned per PH/s per day declines over time

Figure: Daily Bitcoin earned per PH/s over time and as a function of network Hashrate
As of 7/14/2020; historical data since 1/1/2018

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Profitability per PH/s falls as Hashrate increases

- We examine the breakeven profitability on a per PH/s basis at current price levels
- The S9 class can mine profitably at current price of $9220 with 1c/kWh cash costs at network Hashrate up to 180 EH/s
- The next gen S19 class of rigs are profitable at Hashrates up to 295EH/s and power prices of 3c/kWh
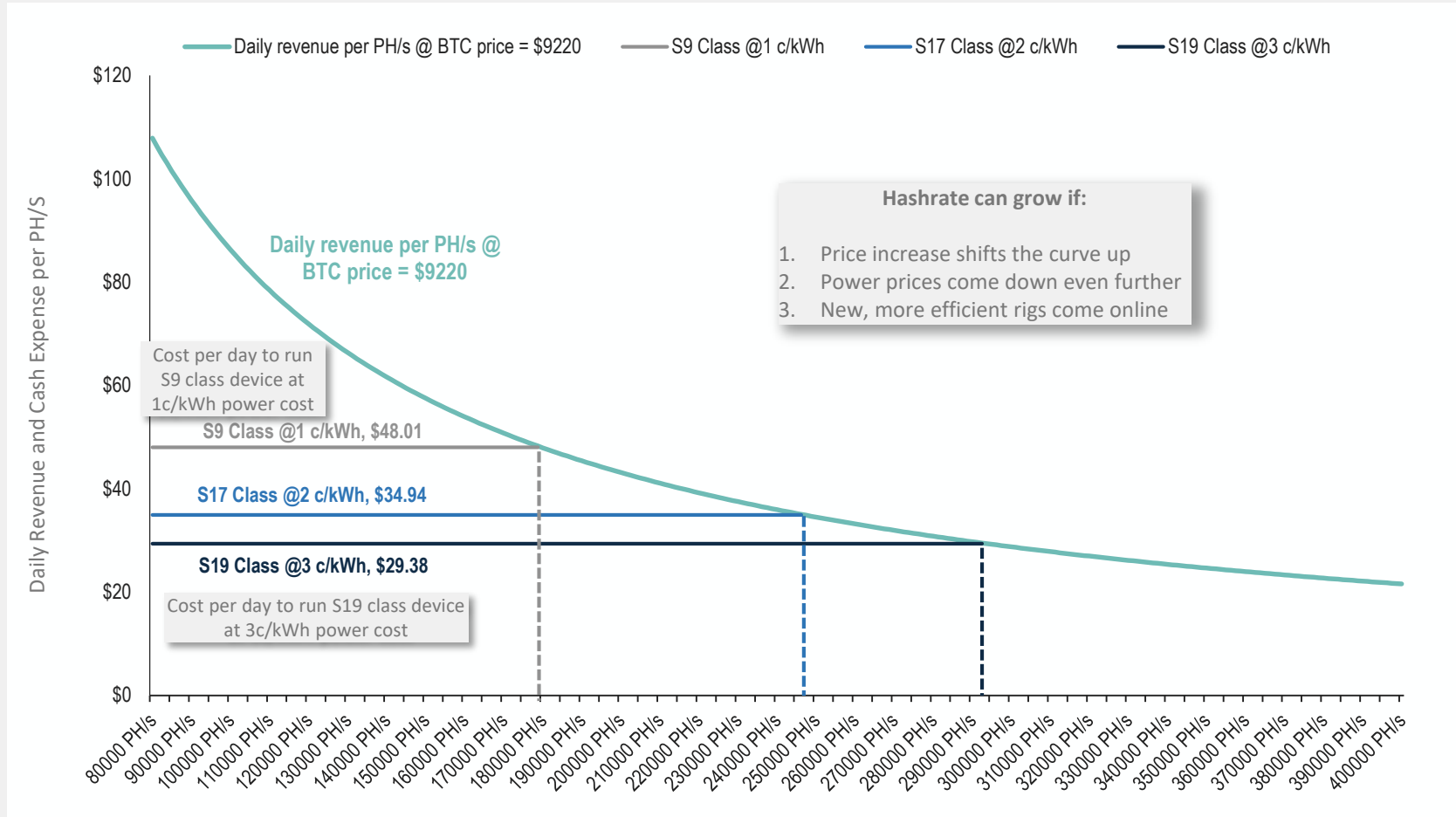

Figure: Daily Revenue earned and Cash Expense per PH/s as a function of network Hashrate As of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

BitOoda

BTC Flow / Hashrate relationship in per MWh terms

- Bitcoin earned per MWh falls with increasing Hashrate, and is a function of the power efficiency of the rig generation in use
- Any mining project must factor in future Hashrate / network power capacity projections in their budget projections
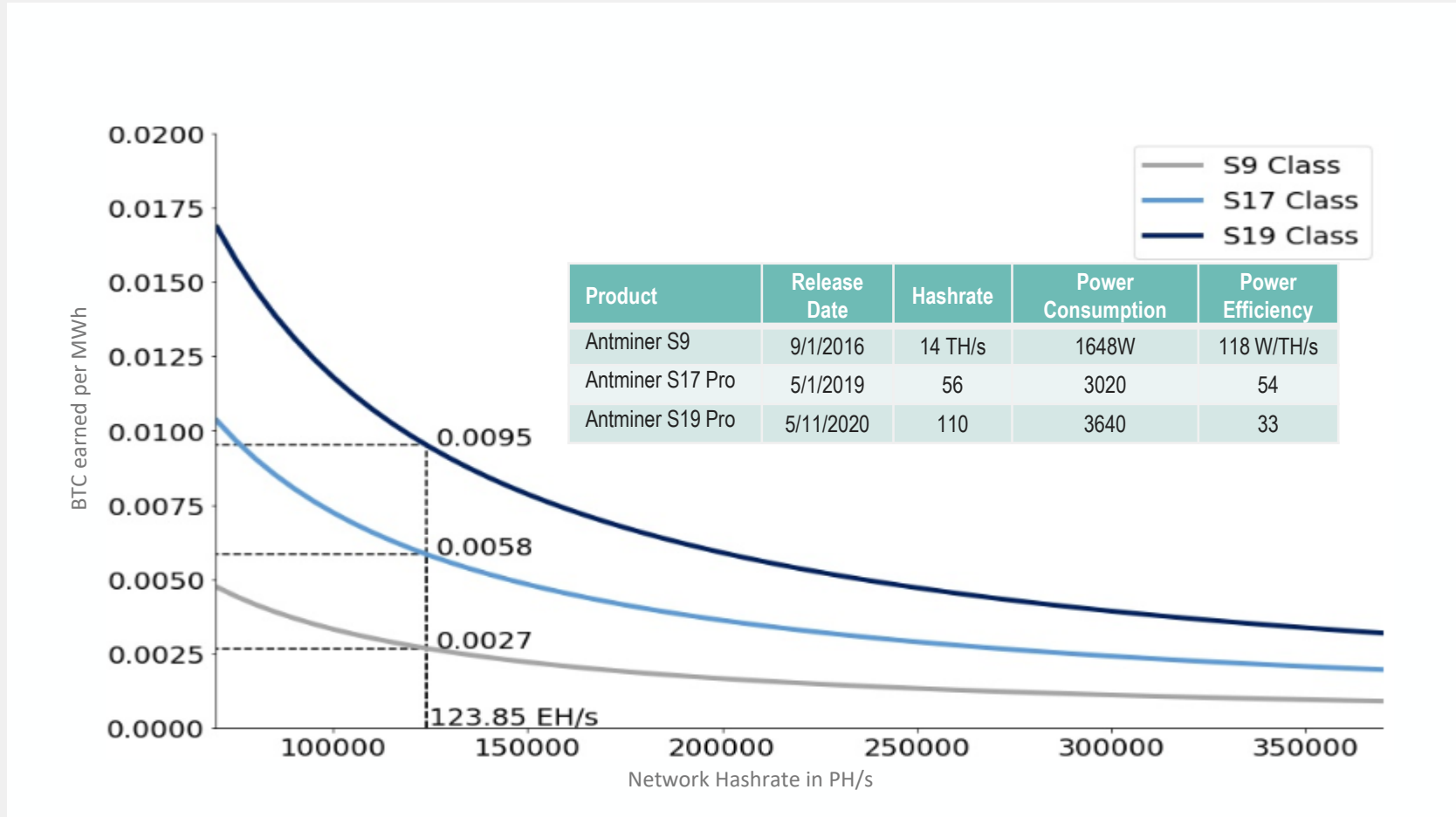

Product	Release Date	Hashrate	Power Consumption	Power Efficiency
Antminer S9	9/1/2016	14 TH/s	1648W	118 W/TH/s
Antminer S17 Pro	5/1/2019	56	3020	54
Antminer S19 Pro	5/11/2020	110	3640	33

Figure: Bitcoin earned per MWh as a function of network Hashrate
As of 7/14/2020

BitOoda

$60 – 105 Revenue / MWh for S17 / S19 class rigs

Revenue per MWh at current 123.85 EH/s Target Hashrate and $9220 Bitcoin price is ~$54 for S17 class equipment, ~$88 for next gen S19 class rigs, but just $25 for older S9 class rigs

Legend:
- S9 Class Current BTC Price +/- $1000 Band
- S17 Class Band
- S19 Class Band
- Revenue @123.85 EH/s and BTC Price of $9220

10EH/s delta offsets a $1000 price delta

BTC price needs to be ~$21000 to be margin neutral at 260 EH/s in 12 months

Y-axis: Revenue in USD per MWh
X-axis: Network Hashrate in PH/s

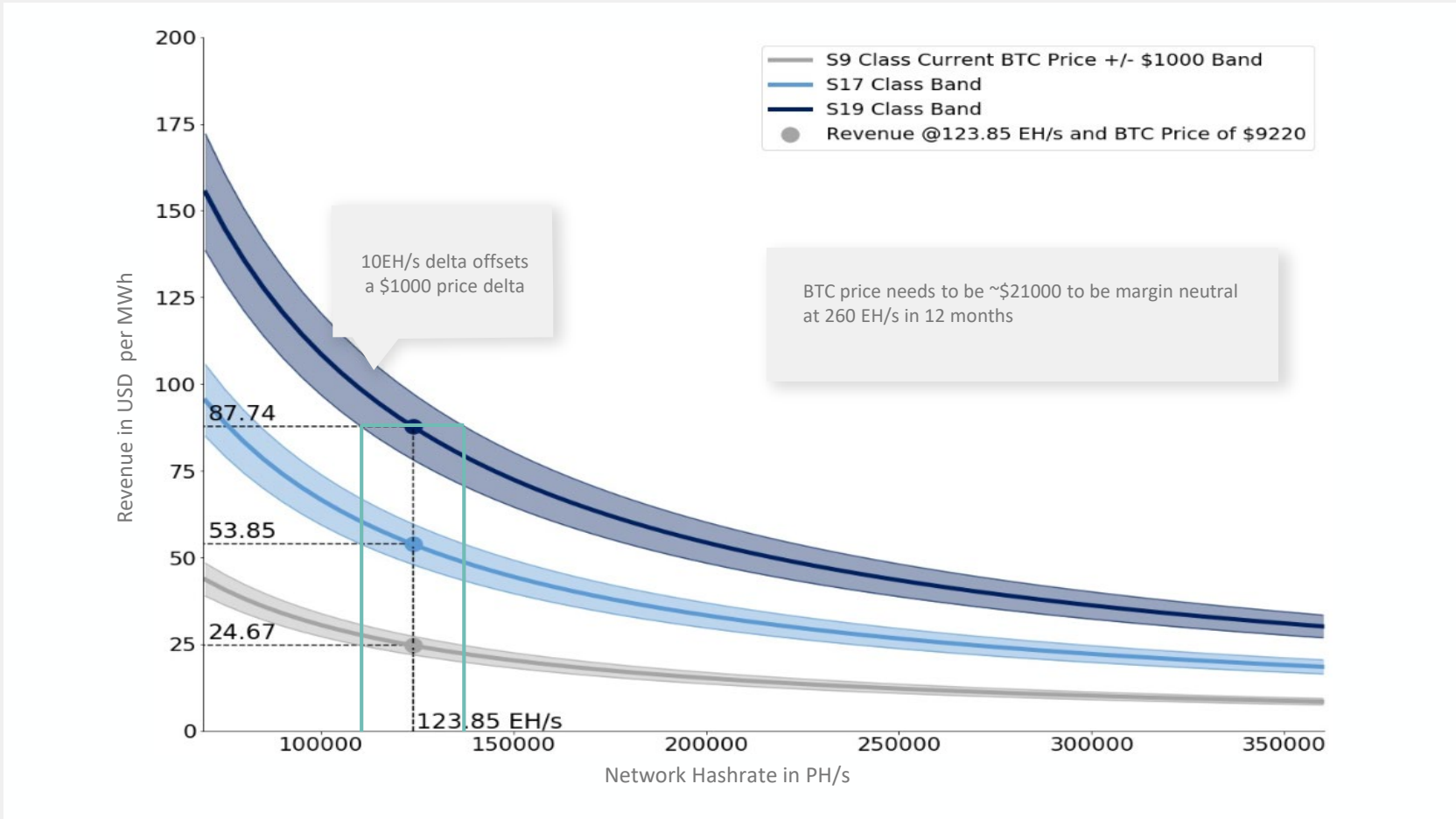Data points: 87.74, 53.85, 24.67 at 123.85 EH/s

Figure: Revenue generated per MWh for different classes of mining rig based on network Hashrate, and BTC price
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda estimates, Blockchain.com, Kaiko, Coinmetrics

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Hashrate Growth Constraints: Price, Power, Production Capacity

BitOoda

$4.5B in 12- month Capex
Needed to achieve 260 EH/s

- We assess the installed base of S17 class rigs was ~1.5mm units as of mid-May 2020
- Over the next year, an additional $4.5 billion in capex is needed to add another ~2.3mm rigs to fully utilize the projected 10.6GW of power supply
- While newer S19 / M30 class rigs are preferred, we believe supply constraints will persist through 2020, leading to continuing sales of S17 class rigs
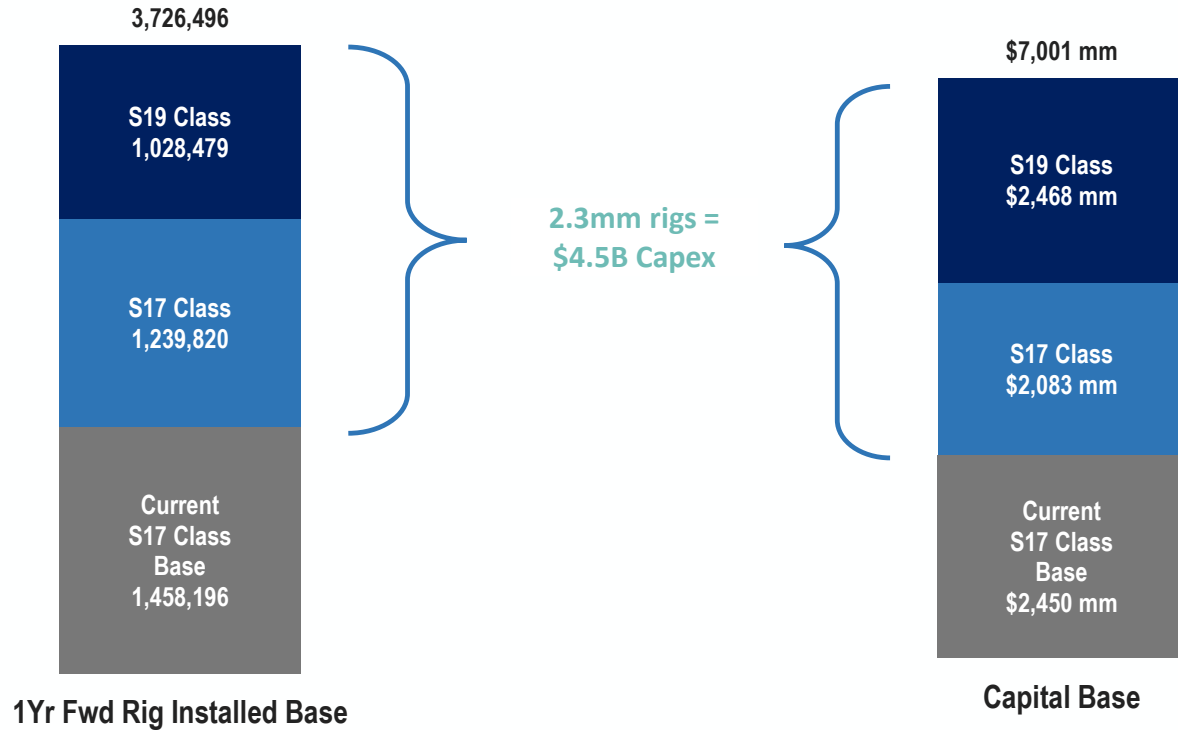
3,726,496

S19 Class
1,028,479

S17 Class
1,239,820

Current
S17 Class
Base
1,458,196

1Yr Fwd Rig Installed Base

2.3mm rigs =
$4.5B Capex

$7,001 mm

S19 Class
$2,468 mm

S17 Class
$2,083 mm

Current
S17 Class
Base
$2,450 mm

Capital Base

Figure: Bitcoin Hashrate and power consumption
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

BitOoda

Hashrate growth
constrains capacity growth

- We focus attention on the internal generation and funding gap, as we view this as most consequential

- **As Hashrate increases, revenue per PH/s falls, while costs remain the same for a given rig class.**

- **As a result, internal generation of funds falls, increasing the funding gap over time.**

- **The price of BTC is thus a critical constraint on the ability of the mining industry to ramp up capacity, as well as on the viability of newly funded projects.**

- **A second, related constraint is the availability of funding at reasonable terms to close the gap: funding needs are lower if internal generation is higher.**

- **Absent capital constraints, the next constraint is the capacity of rig manufacturers to deliver the volumes needed to achieve our hash projections.**

- **Finally, available power capacity is a constraint that sets a (moving) upper limit on rigs in operation. We have modeled a 10% p.a. growth in total available power at viable price points, from an estimated recent maximum available power of 9.6GW.**

- **We believe semiconductor capacity will prove sufficient to meet demand. Our model assumes delivery volumes that are well within historical norms. At peak, Bitmain alone shipped as many as 2.56 million units in 6 months. However, near term supply constrains remain, including lingering Covid-related supply chain disruptions as well as reported shipment delays at Bitmain related to disagreements among the founders.**

- **The key constraint we examine here is internal generation and the funding gap.**

BitOoda

Revenue / MWh: **Hash growth offsets price**

- Our conservative model assumes revenue / MWh falls from ~$100 to $60 for S19 class rigs, **even with price appreciating to $19k in 24 months**
- We do not factor in any further average power price declines for the network, but note that both flaring and intermittent / demand response operations are intended to have average power prices far below the network average
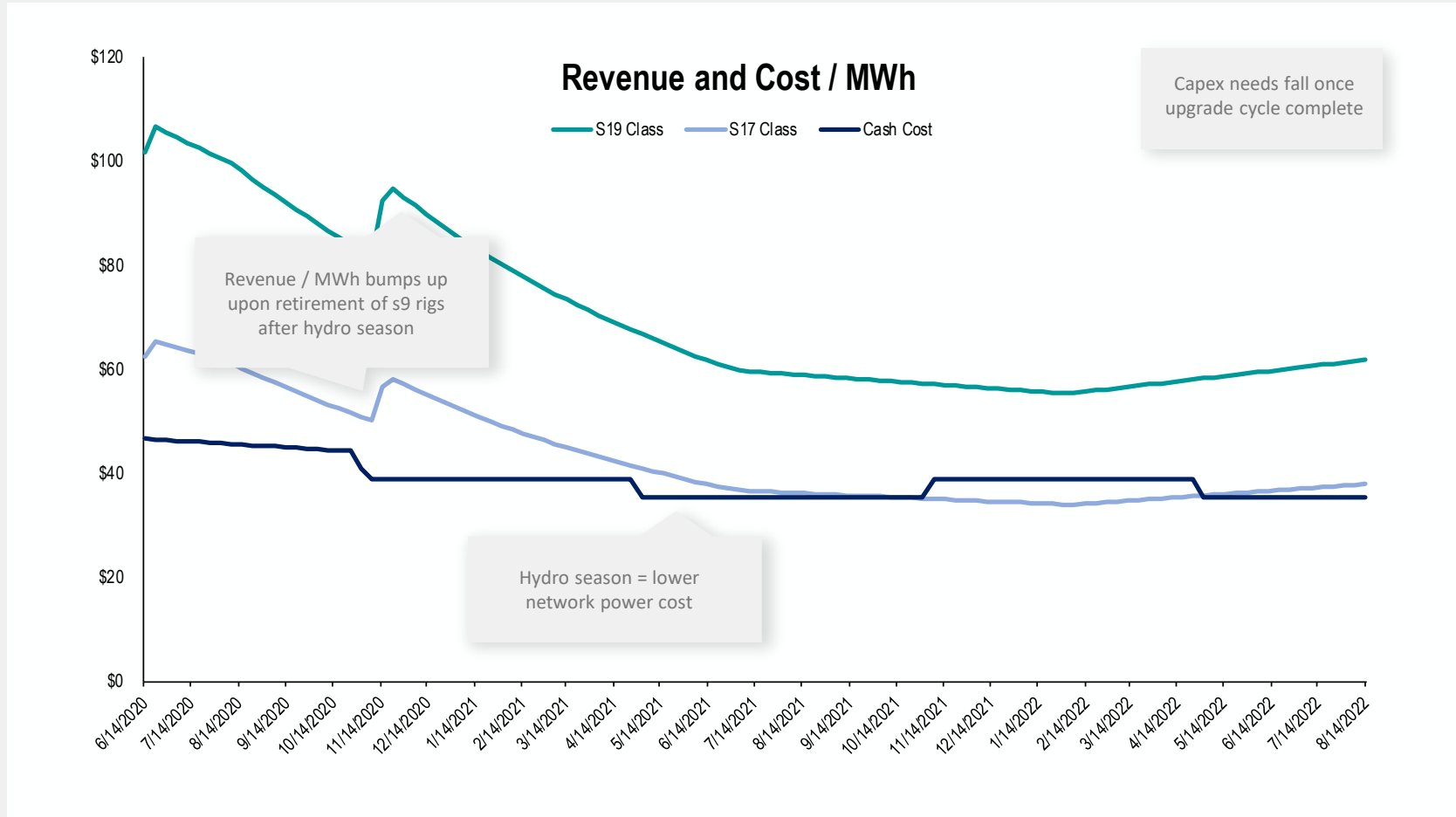

Revenue and Cost / MWh

S19 Class   S17 Class   Cash Cost

Capex needs fall once upgrade cycle complete

Revenue / MWh bumps up upon retirement of s9 rigs after hydro season

Hydro season = lower network power cost

Figure: Revenue and cost per MWh
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

$4.1 B funding gap
Over next 18 months

- Internal generation for the industry assumes BTC price grows steadily to ~$19k in 2 years, although many industry participants might model a higher price
- Per our model, the Bitcoin mining industry will need $4.1B in external funding to support expansion through the end of 2021
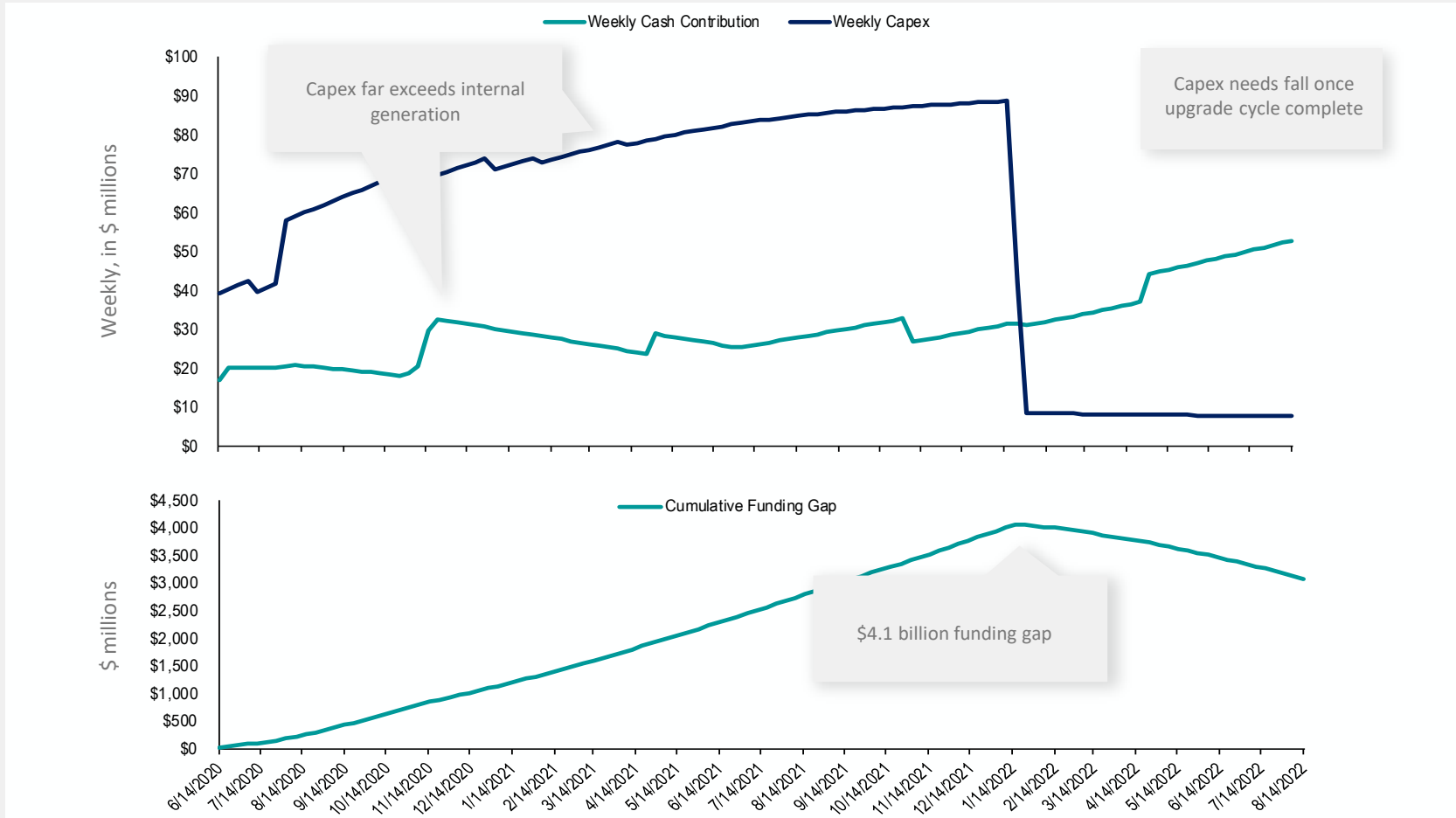- The ability to raise financing is the second boundary condition limiting Hashrate

Weekly Cash Contribution — Weekly Capex

Capex far exceeds internal generation

Capex needs fall once upgrade cycle complete

Cumulative Funding Gap

$4.1 billion funding gap

Figure: Bitcoin network capex and internal generation
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

BitOoda

60k Weekly Shipments Achievable: **No Capacity Constraint**

- Concerns have been raised about the ability of manufacturers to deliver the 60k units per week built into our Hashrate projections
- However, Bitmain filings (IPO prospectus, pp 163) reveal they were able to deliver over 95,000 S9s per week in 2018
- **The industry has the ability to ship >150k devices a week**, although we believe shipments will likely be lumpy based on wafer deliveries from the foundries
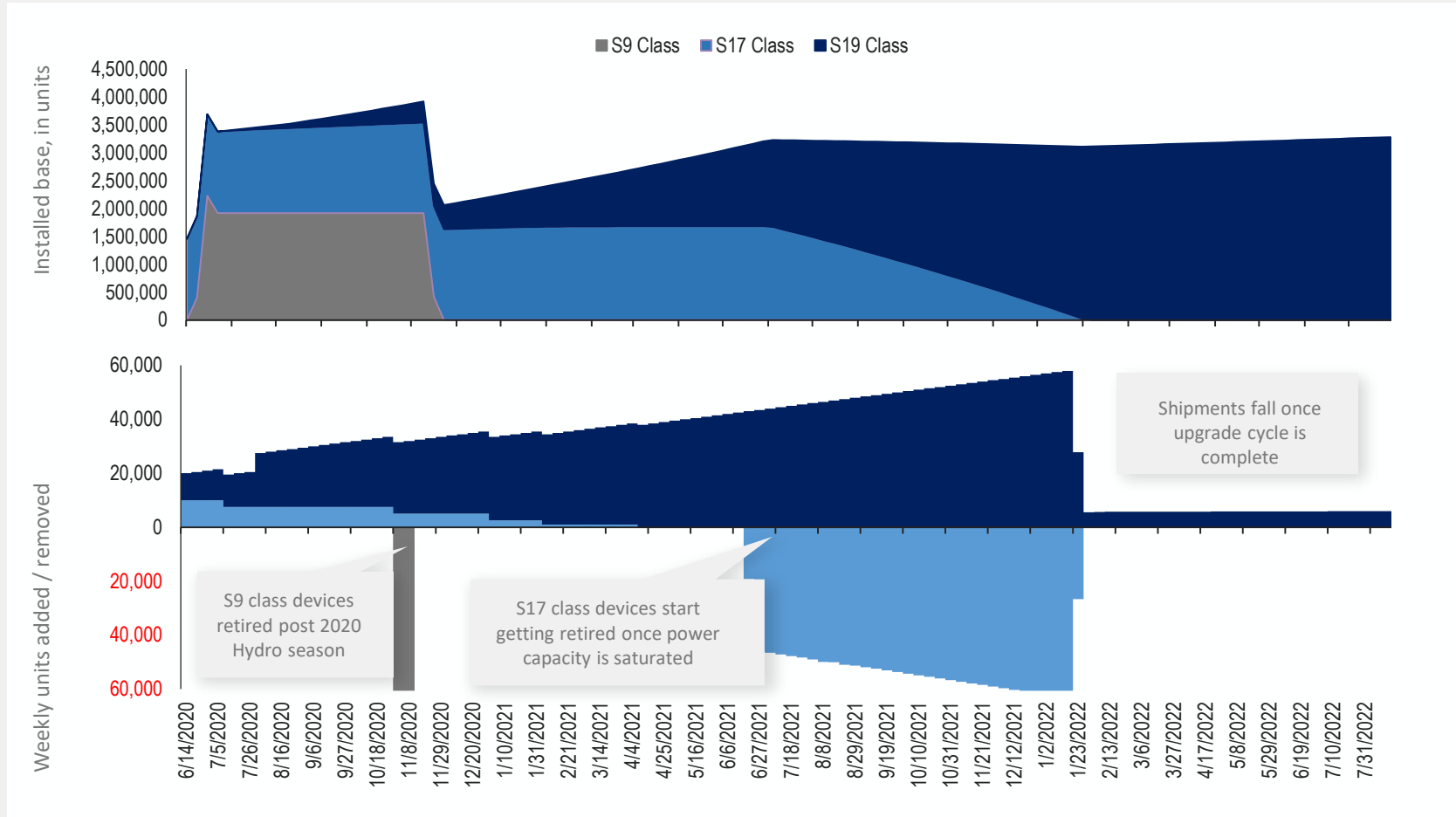

■ S9 Class   ■ S17 Class   ■ S19 Class

Installed base, in units

Weekly units added / removed

Shipments fall once upgrade cycle is complete

S9 class devices retired post 2020 Hydro season

S17 class devices start getting retired once power capacity is saturated

Figure: Bitcoin network capex and internal generation
Note: We assume a PUE of 1.12 to estimate share of power actively used to mine Bitcoin
As of 7/14/2020

Source: BitOoda, Blockchain.com, Kaiko, Coinmetrics

BitOoda

7nm and 5nm should dominate rig shipments through 2022

- The next major step in ASIC technology will come with the ramp up in 5nm technology. At this node, TSMC, the primary supplier to Bitmain, has a lead over Samsung, the other major foundry.
- While TSMC is seeing volume orders at both 7nm and 5nm nodes, their process geometries look similar to Intel's 10nm node
- We believe Samsung also features a tighter process geometry, so Samsung is close behind TSMC.
- Samsung recently announced that plans for commercial production on a 3nm process node would likely be delayed into 2022, while 5nm will likely be the mainstay of 2021 production (See this news article).
- We believe the dearth of 3nm capacity and likely initial low yields will lead to 5nm processes being the mainstay of ASIC development and production through 2022.
- Thus S19 class rigs will form the bulk of shipments in the next 24 months, although incremental design improvements could lead to efficiency gains that could be reflected in new model lineups.

Comparison of Intel's and TSMC's Process Technologies

	Intel 14nm	Intel 10nm	TSMC 10nm	TSMC 7nm
Fin Pitch	42nm	34nm	36nm	30nm
Gate Pitch	70nm	54nm – HD	66nm	57nm – HD 60nm – HP
Min Metal Pitch	52nm	36nm	42nm	40nm

Figure: Comparison of Intel and TSMC process geometry   *Source*: https://www.eetimes.com/intels-10nm-node-past-present-and-future/

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Appendix and Sources

BitOoda

Appendix:
Select Equipment
Efficiency Statistics

- New equipment offers superior operating performance with capital and power efficiency gains
- With next generation equipment offering lower cash cost than the old, the price of a new prior generation rig needs to be low enough that the total cost to mine, including depreciation is comparable for both models
- This is what we mean by the "displace" price – the needed price for a rig to be competitive with the newer rig that is displacing it

Product	Price		Date		Metrics			Price per TH/s	
	Release	Displace	Release	Displace	Hash Rate in TH/s	Wattage	Watts per TH/s	Release	Displace
AntMiner S1	1840	283	11-01-2013	04-01-2014	0.2	403	2240.0	10222.0	1575.0
AntMiner S2	2259	225	04-01-2014	12-01-2014	1.0	1232	1232.0	2259.0	225.0
AntMiner S5	370	276	12-01-2014	09-30-2015	1.2	660	572.1	320.0	239.0
AntMiner S7	1823	390	09-30-2015	09-01-2016	4.9	1355	278.8	375.0	80.0
Antminer S9	2100	210	09-01-2016	12-01-2018	14.0	1647	117.7	150.0	15.0
Antminer S15	1475	976	12-01-2018	04-01-2019	28.0	1787	63.8	52.0	34.0
AntMiner S17 Pro (50TH)	2195	1895	04-01-2019	04-28-2019	50.0	2212	44.2	43.0	37.0
Antminer T17	1600	1065	04-28-2019	05-01-2019	40.0	2464	61.6	40.0	26.0
Antminer S17 Pro	1680	1466	05-01-2019	05-11-2020	56.0	3019	53.9	30.0	26
AntMiner S19 Pro	2400	2380	05-11-2020	07-06-2020	110.0	3640	33.1	21.0	21
Whatsminer M30s*	-	-	05-10-2020	-	88.0	3344	38.0	-	-
Avalon 1066 Pro*	1100	-	04-06-2020	-	60.0	3200	53.3	-	-

Figure: Select Bitcoin mining rig details
Note: Since 2013

Source: BitOoda, Bitmain, Canaan, MicroBT

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Appendix:
Rig Classes based on
Efficiency Statistics

- Each generation of mining rigs exhibits similar power efficiency per TH/s across manufacturers.
- Thus, it makes sense to simplify analysis based on "generation" or "class" rather than individually by model.
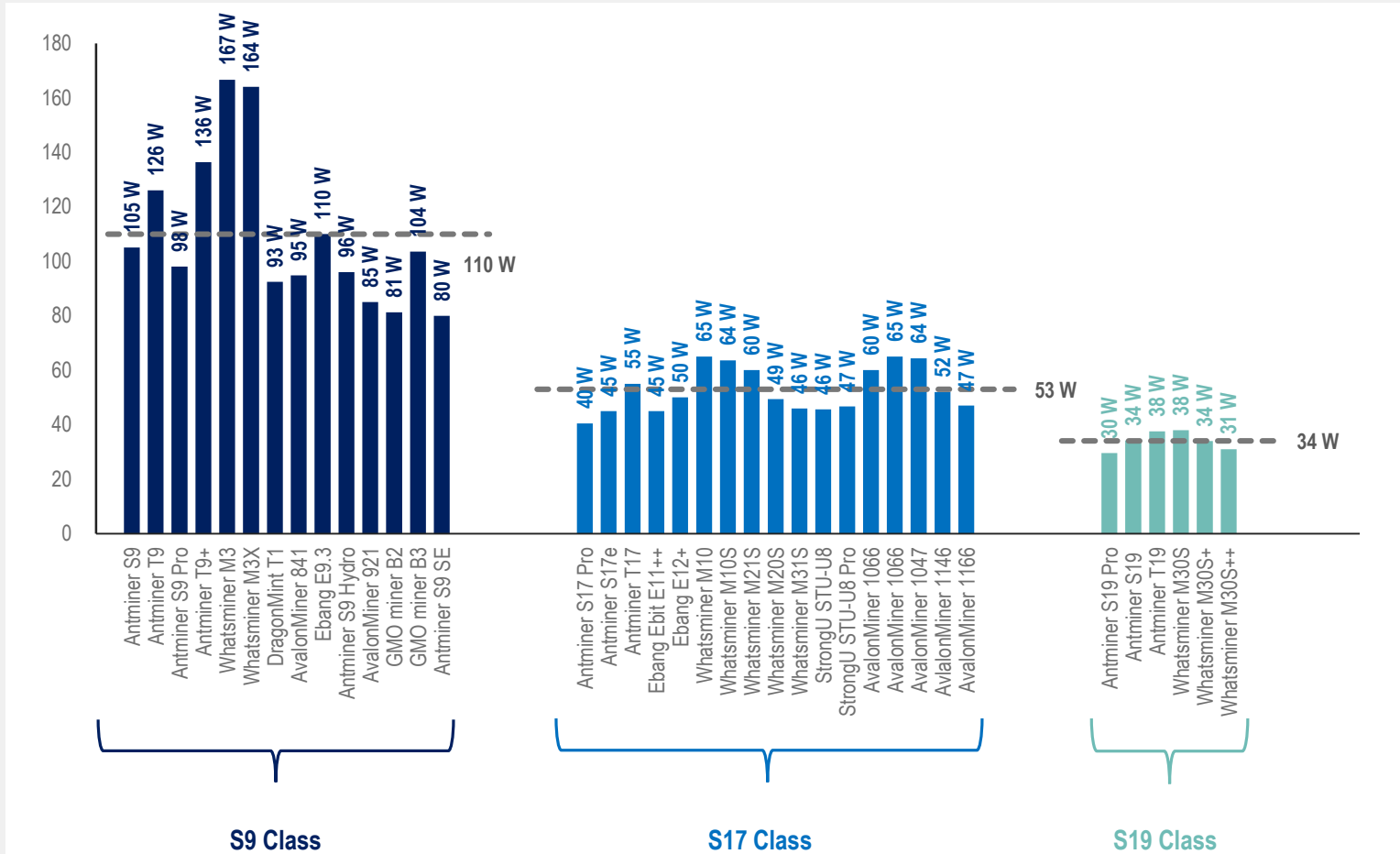- We use Bitmain models as a generic for each class of rig

Figure: BitOoda classification of rigs into key classes

Source: BitOoda, Bitmain, Canaan, MicroBT, Halong, GMO, AsicMinerValue.com

Sources:

Much of the most sensitive data came from direct conversations with miners, rig manufacturers, and distributors / resellers as well as hosting data providers. The resulting data was more detailed than publicly available, but shared on condition that no raw data nor any personally identifiable information would be published. We have respected that. Where possible, we also used public sources to further build our overall view of the mining space.

Core Sources:
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- Kaiko.com
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