Blockchain technology and energy consumption: The quest for efficiency

Prepared by MNP

MNP.ca

About MNP

MNP is a leading national accounting, tax, and business consulting firm in Canada. We proudly serve and respond to the needs of our clients in the public, private, and not-for-profit sectors. Through partner-led engagements, we provide a collaborative, cost-effective approach to doing business and personalized strategies to help organizations succeed across the country and around the world.

Disclaimer

The opinions and conclusions identified in this independent review of blockchain energy consumption do not constitute a legal opinion, nor do they constitute a third-party attestation or statement of audit opinion as defined by the American Institute of Certified Public Accountants / Chartered Professional Accountants Canada (AICPA/CPA Canada) rules and definitions. This assessment makes no warranty regarding the claims made about the current or future state of the Bitcoin ecosystem and its various implementations. This engagement was performed at a point in time based on resources available to us; therefore, someone else with different access and different resources may have different results. If a third party is to rely on this report, written consent from MNP must be arranged.

Purpose of this document

The purpose of this document is to establish a transparent framework for estimating power consumption of any SHA-256[1] blockchain. In addition, MNP aims to determine which protocol chosen from a sample of Bitcoin SHA-256 blockchains is more energy efficient.

Energy estimates for the sampled Bitcoin protocols were established by examining previously published reports for Bitcoin energy consumption. Publicly available information was leveraged regarding Canadian cryptocurrency miners' operations, and relevant data from each respective blockchain sampled. This report summarizes the context, methodologies used, and conclusions in the following sequence:

A. Preamble

B. Cryptocurrency mining and energy impact

C. Modeling approach

D. Results

E. Conclusion

1 SHA-256 is used in some of the most popular authentication and encryption protocols, including SSL, TLS, IPsec, SSH, and PGP. In Unix and Linux, SHA-256 is used for secure password hashing. Cryptocurrencies such as Bitcoin use SHA-256 for verifying transactions.

Scope and approach

To perform this study a sample of Bitcoin SHA-256 blockchains were assessed: Bitcoin Core, Bitcoin Satoshi Vision, and Bitcoin Cash implementations. The areas used in the comparison were as follows:

- Block difficulty
- Block size
- Number of transactions
- Estimated periodic energy consumption

This study was performed between June 8 and July 29, 2021 using publicly available documentation. All conclusions and key findings were based on the following assessment procedures:

- Defining key criteria for determining the energy consumption of a Bitcoin network
- Establishing a logic model and key variables for calculating energy consumption for any SHA-256
- Reviewing publicly available content and documentation to evaluate each protocol implementation against assessment criteria
- Comparing results of our estimation model with real-world data from a large Canadian cryptocurrency miner
- Conducting interviews with key stakeholders and subject matter experts to validate our logic model and study results

Limitations, boundaries, and exclusions

For the purposes of this study, the scope was limited to examining Bitcoin Cash, Bitcoin Core, and Bitcoin Satoshi's Vision. Due to time and material constraints, other forks of the original Bitcoin protocol were excluded.

The following review areas were not addressed as part of the independent review:

- **Valuation** - There is no intent to address the mechanisms that inform the market pricing of any digital cash mentioned in this paper. If mentioned, any forward-looking valuations are purely hypothetical and do not constitute investment advice.
- **Reputation** - There is no intent to address the public perceptions of any digital cash and/or the operators of the digital cash networks mentioned in this report.
- **Other SHA-256 Protocols** - The analysis of other SHA-256 proof-of-work blockchain protocols, such as Litecoin, were not included in our analysis.

Table of Contents

Preamble 5

Cryptocurrency mining and energy impact 5

Previous work 7

Canadian mining operations 8

Our modeling approach 9

Model results 15

Conclusion 18

Appendix 1 – Mining equipment 19

Appendix 2 – Canadian miners surveyed 20

Appendix 3 – Canadian miner equipment 21

Appendix 4 – Assumptions framework 22

Preamble

In Canada, there are approximately 12 publicly traded firms whose main business revolves around providing the infrastructure for processing cryptocurrency transactions — otherwise known as cryptocurrency mining. It is relatively common knowledge that mining cryptocurrency consumes a significant amount of electricity.[2,3] During the timeframe of this report (June to July 2021), there had been increasing mainstream news and social media coverage of the energy consumption impacts of Bitcoin and other blockchain technologies, as well as rhetoric surrounding blockchain technology and green energy issues.

For the purposes of this report, three implementations of the Bitcoin Protocol were selected for examination: Bitcoin Satoshi's Vision (BSV), Bitcoin Cash (BCH), and Bitcoin Core (BTC). Each of the selected digital paymentnet-works rely on similar mining technology and have a shared protocol which makes the comparison straightforward.

As more businesses and consumers adopt blockchain technologies, and regulatory requirements towards green and renewable energy continue to become more stringent, it is important to understand the impact blockchain has on the environment — especially related to the energy consumption issue. The environmental impact of a blockchain leads to two important questions:

- Is it possible to accurately estimate the power consumption of a blockchain network?
- Is there a more efficient blockchain implementation when comparing kilowatt hours consumed per block?

In determining the answers to the above questions, this study found it is possible to estimate a blockchain network's power consumption. Moreover, we may use these estimates in assessing which implementations are more efficient. Of the three cryptocurrencies that were sampled, our findings indicate BSV is a more efficient blockchain network when compared to other two sampled SHA-256 proof-of-work blockchains.

Cryptocurrency mining and energy impact

To assess the efficiencies of several cryptocurrencies and their underlying blockchain protocols, it is important to understand how the process of cryptocurrency mining works. For Bitcoin, a Hashcash[4] style proof-of-work [5,6], (PoW) in combination with a timestamp server is used to validate transactions.

2 P. Evans. Bitcoin is an energy hog: New numbers suggest how big a problem it is. (May 22nd, 2018). CBC News. Retrieved on August 8th, 2021 from https://www.cbc.ca/news/business/bitcoin-electricity-1.4668768

3 N. Carter. How Much Energy Does Bitcoin Actually Consume? (May 5th, 2021). Harvard Business Review. Retrieved on August 8th, 2021 from https://hbr.org/2021/05/how-much-energy-does-bitcoin-actually-consume

4 Hashcash is a proof-of-work algorithm and was invented by Adam Back in 1997

5 Proof-of-Work is a form of cryptographic zero-knowledge proof in which one party (the prover) proves to others (the verifiers) that a certain amount of effort has been expended. Verifiers can subsequently confirm this expenditure with minimal effort on their part.

6 Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. https://nakamotoinstitute.org/static/docs/bitcoin.pdf

PoW is the consensus mechanism used by all Bitcoin protocols to validate transactions and blocks. The algorithm begins by scanning for a value that, when hashed with SHA-256, has a beginning with a certain number of zero bits.[7] This process can be made more difficult by increasing the required number of zeros or made less difficult by reducing the number of zeros. This is the basis of work. Using the hash of multiple values and an incrementing random number (the nonce), a central processing unit (CPU) can find a solution with the required amount of beginning zeros after a certain period of effort. Once the required work has been completed, the block is added to the chain of previous blocks and this process continues. CPU effort (where much of the energy is consumed) is required to satisfy the PoW. As new blocks get added, PoW makes it increasingly difficult to change previous blocks because the work to satisfy the PoW mechanism would need to be revisited.

The network is powered by node operators, who provide CPU power to the network in exchange for an incentive reward and transaction fees. The node operators are rewarded with amounts of Bitcoin every time they win the right to create a new block and add it to the chain. The total supply of Bitcoin is limited to 21 million coins, with fresh coins added to circulation via the winning node operator in the amount of the fixed subsidy portion of the block reward. The subsidy portion of the block reward is halved every 210,000 blocks (approximately every four years) first to 25, then 12.5, 6.2, 3.125 and so forth until the full 21 million supply of fresh coins is circulated. As of September 2021, the incentive is at 6.25 fresh Bitcoin per successful block. As the number of fresh coins in the network grows, transaction fees (also earned by winning node operators for each block) will eventually need to grow as replacement for the block rewards — especially once the 21 million supply limits of fresh coins is reached.[8]

Additionally, miners / node operators compete amongst themselves to win the right to add a new block to the blockchain. A miner's hashpower, as compared to the total hashpower of the network, determines a miner's expected share of block rewards. This hashpower race becomes critical for a miner's profitability in determining which cryptocurrency to mine. Once the cryptocurrency is selected, mining and node operators employ specialized equipment that efficiently and effectively perform the mining operation.

In the early days, miners could compete with consumer-grade CPUs. This eventually shifted to miners using graphics processing units (GPUs) which are significantly more efficient in calculating hashes. However, there remains an economic trade off, as GPUs are considerably more expensive than CPUs. With the healthy competition among miners, application-specific integrated circuits (ASICs) have become the most popular choice for Bitcoin miners. ASICs are highly specialized, single-purpose machines which are quite efficient at performing the hashing operation required to successfully write a new block.

It is also important to note not all ASICs are created equal. Like the difference between CPUs and GPUs, some ASICs are more efficient than others. The earliest ASICs were power hungry compared to those available today. They also are priced accordingly, with the newest and most efficient machines being more expensive than the older machines. The economic puzzle of cost versus efficiency plays an important role in how miners choose their equipment.

The equipment decision is the key determinate in how much energy a Bitcoin network will consume in a given time period. This equipment mix also impacts the difficulty metric of a Bitcoin blockchain protocol and the network supporting and running this protocol.

7 Ibid

8 Nakamoto, S. (2010). Bitcoin Forum. https://Bitcointalk.org/index.php?topic=994.msg12168 - msg12168

Previous work

There have been several studies dedicated to estimating energy consumption, particularly for the BTC implementation. These studies all provide valuable information when determining how to best estimate the consumption of a network.

Author	Date	Title
Stoll, C., Klaaßen, L., and Gallersdorfer, U.	June 2019	The Carbon Footprint of Bitcoin
Zade, M., Myklebost, J., Tzscheutschler, P., and Wagner, U.	March 2019	Is Bitcoin the Only Problem? A Scenario Model for the Power Demand of Blockchains
McCook, H.	August 2018	The cost & sustainability of Bitcoin
De Vries, A.	May 2018	Bitcoin's Growing Energy Problem
Vranken, H.	October 2017	Sustainability of Bitcoin and blockchains
Hayes, A. S.	March 2015	A Cost Production Model for Bitcoin
O'Dwyer, K.L., and Malone, D.	September 2014	Bitcoin Mining and its Energy Footprint

Equipment selection is a major theme shared by each of the papers above. Whether the authors are approaching energy consumption from the top-down or bottom-up, the equipment acting as the backbone of a cryptocurrency's blockchain network is what effectively determines the network's power consumption. The authors all faced the same difficulty in attempting to determine an accurate mix of equipment in their energy consumption calculations.

These studies provide an initial foundation for us to develop an assessment model for determining the network energy consumption of a particular Bitcoin implementation (See Appendix 4 for our assumptions framework). For SHA-256 cryptocurrencies, miners are faced with effectively the same equipment decision. With an appropriate approximation of all the equipment on the network, it is possible to accurately estimate its power consumption.

Canadian mining operations

Given the high degree of influence mining equipment has on power consumption, this study surveyed publicly available data from publicly traded Canadian cryptocurrency miners to derive a typical mix of mining equipment in use.

Shared infrastructure

A survey of 12 Bitcoin mining companies with facilities in Canada (Appendix 2) reveals many focus their investments on power infrastructure. They provide facilities with the capacity to consume megawatts of power, establishing contracts for more cost-effective energy sources than those available in broader international markets. They also operate as co-location and hosting companies, selling the use of their facilities to smaller miners — who in turn get the benefit of inexpensive power, real estate, and infrastructure management.

Trading efficiency for value

Mining companies have two main expenses — mining equipment and the cost of power. Companies may not always purchase the most efficient mining equipment to help reduce their cost of power. The upfront cost of equipment may have a larger impact on the decision than a reduction in energy consumption.

For example, based on public documents released by Argo Blockchain in October 2019, Argo cancelled an order for 5,000 Bitmain S17 miners, opting instead for 10,000 Bitmain T17 units. The T17 consumes 10 watts more per tera-hash (Th) calculated than the least efficient S17 model. That is, 5,000 T17 miners will consume 9.25 gigawatt-hours more per month than the same number of S17 units.

However, Argo is getting nearly twice the hashrate for less than two-thirds the upfront cost. The new order cost them US$9.5 million instead of US$13 million and produces 150 peta-hashes per second more, giving Argo Blockchain a larger share of the overall network hashrate.

Model	Number of units	Total cost	Power efficiency	Unit power consumption	Total power consumption	Unit hashrate	Total hashrate
Bitmain S17[9]	5000[10]	13.09M USD[11]	45 W/Th/s[12]	2200W[13]	11MW	50Th/s	250Ph/s
Bitmain T17[14]	10000[15]	9.51M USD[16]	55 W/Th/s[17]	2385W[18]	23.85MW	40Th/s	400Ph/s

Given the value proposition of a higher hashrate for less upfront cost, it seems likely other miners have made similar compromises on the power consumption efficiency of their equipment.

9 S17 Specifications. (April 9th, 2019). Bitmain Support. Retrieved August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/360020208593-S17-Specifications

10 Press Release. (July 4th, 2019). Argo Blockchain PLC. Retrieved August 8th, 2021 from https://polaris.brighterir.com/public/argo_blockchain/news/rns/story/w6l2dqw

11 Ibid

12 S17 Specifications. (April 9th, 2019). Bitmain Support. Retrieved August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/360020208593-S17-Specifications

13 Ibid

14 T17 Specifications. (May 7th, 2021). Bitmain Support. Retrieved August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/360020445993

15 Press Release. (October 30th, 2019). Argo Blockchain PLC. Retrieved August 8th, 2021 from https://polaris.brighterir.com/public/argo_blockchain/news/rns/story/xey8kzw

16 Ibid

17 T17 Specifications. (May 7th, 2021). Bitmain Support. Retrieved August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/360020445993

18 Ibid

Immersion cooling and improved performance

In mid-2019, DMG Blockchain (DMG) announced it would begin developing an immersive cooling solution for blockchain miners.[19] In early 2020, they announced they had begun testing their solution to reduce their cooling costs and improve the performance of their machines.[20] Immersion cooling involves submerging equipment into a non-conductive fluid which is used as a medium for heat exchange. Fans are not required for submerged mining equipment. DMG claims they can increase the hashrate of equipment by 30 percent when cooled by immersion.[21]

In 2021, DMG committed to converting 60MW of their infrastructure to immersion cooling. They state the 60MW equates to approximately 2Eh of miners.[22] This would infer their approximate average equipment efficiency to be 30W/Th. For context, the lowest publicly available manufacturer efficiency specification at the time of writing is the Bitmain S19 Pro, at 29.5W/Th.[23] According to their public documents DMG is running a mix of new and old equipment, so this would seem to validate the success of immersion cooling.

Our modeling approach

Our model's approach compares the consumption in kilowatt-hours (kWh) per block, kWh per transaction (tx), and kWh per megabyte (MB). The model must consider what is being produced per unit of energy with respect to energy consumption when comparing the different Bitcoin protocols.

Miners mine individual blocks. Each block is comprised of zero, one, or more transactions. Transaction size may vary depending on several factors, including any arbitrary data it contains.

Throughputs, as discussed here, are subsidiary to blocks. Since a block may be mined with a minimum density that has a minimal storage size and contains no transactions — or a maximum density that will vary depending on the protocol — the throughputs become a significant distinguishing factor between the different protocols with respect to energy consumption.

19 DMG Blockchain Solutions Partners with Immersion Cooling Systems Company SixtyOneC to Co-develop the Most Cost-Efficient Crypto Mining. (May 16th, 2019). GlobeNewswire. Retrieved on August 8th, 2021 from https://www.globenewswire.com/news-release/2019/05/16/1826228/0/en/DMG-Blockchain-Solutions-Partners-with-Immersion-Cooling-Systems-Company-SixtyOneC-to-Co-develop-the-Most-Cost-Efficient-Crypto-Mining.html

20 DMG Implementing Immersion Cooling Retrofitting at Facility. (February 11th, 2020). GlobeNewswire. Retrieved on August 8th, 2021 from https://www.globenewswire.com/news-release/2020/02/11/1983127/0/en/DMG-Implementing-Immersion-Cooling-Retrofitting-at-Facility.html

21 DMG Conducting Extensive Immersion Cooling Study as it Prepares its Facility for Large-Scale Deployment in 2021. (February 10th, 2021). GlobeNewswire. Retrieved on August 8th, 2021 from https://www.globenewswire.com/news-release/2021/02/10/2173232/0/en/DMG-Conducting-Extensive-Immersion-Cooling-Study-as-it-Prepares-its-Facility-for-Large-Scale-Deployment-in-2021.html

22 Ibid

23 S19 Pro Specifications. (May 27th,2021). Bitmain Support. Retrieved on August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/900000261726-S19-Pro-Specifications

Transactions are the ultimate measure of throughput. The number and size of the transactions in a block will affect the size of the block. BTC has a strictly limited block size approaching 4MB. BCH has a much more permissive limit of 32MB. BSV is unbound by block size. Since mining is what consumes energy, and blocks are the product of mining: the more transactions in a block, the lower the energy consumption per transaction. Similarly, the larger a block can be (measured in megabytes), the lower the energy consumption per megabyte.

The number of miners on a network, their hashpower, and the energy efficiency of their equipment will have a direct effect on the consumption required to mine a block. The energy consumption required to mine a block has a direct effect on the consumption of the other two metrics, since:

$$C_{tx} = \frac{C_{block}}{N_{txBlock}}$$

and

$$C_{mb} = \frac{C_{block}}{N_{mbBlock}}$$

with

$$C_{tx} = Energy\ consumption\ per\ tx\ [KWh/tx]$$

$$C_{mb} = Energy\ consumption\ per\ megabyte\ [KWh/MB]$$

$$C_{block} = Energy\ consumption\ per\ block\ [KWh/block]$$

$$N_{txBlock} = The\ number\ of\ transactions\ in\ the\ block$$

$$N_{mbBlock} = The\ size\ of\ the\ block\ [MB]$$

Notice kWh/tx and kWh/MB are related but will differ based on user behaviour and miner selection. If no user transactions are included in a block, the consumption per transaction will be equal to the consumption per block because the coinbase reward will be the sole transaction. If a miner selects an abnormally large transaction to validate in a maximum capacity block, the consumption per transaction will seem high relative to the consumption per megabyte because there will be fewer transactions. Other metrics could be measured with the same decision-making factors. For instance, to examine the energy consumption per Bitcoin transferred.

$$C_{bitcoin} = \frac{C_{block}}{\sum_{i=2}^{N_{txBlock}} V_{tx,i}}$$

with

$$C_{bitcoin} = Energy\ consumption\ per\ bitcoin\ transfered\ [KWh/bitcoin]$$

$$i = tx\ in\ the\ block$$

$$V_{tx} = the\ value\ of\ a\ transaction$$

Note this equation does not account for change returned to the sender.

Our model

The model MNP developed estimates the energy consumption of the entire network. Our model used block data collated by a multi-chain block explorer[24] to provide the base of the network data from April 1, 2020 to June 13, 2021. The block difficulty is used to determine the probable hashes required to solve the block. By knowing the hashes required to solve a block and the amount of time the network took to solve the block, it's possible to estimate the hashpower of the network (Th/s).

Our model estimates the hashes required to solve a block by the knowing the maximum target is $(2^{16} - 1) \cdot 2^{208}$, and a hash may have 2^{256} possible results. Thus, the hashpower required to solve a block of difficulty 1 $\frac{2^{256}}{(2^{16}-1)\cdot 2^{208}} \approx 2^{32}$. [25,26] The expected hashpower scales linearly with difficulty, D. The number of hashes expected for all the blocks can be found with

$$A = D_\mu \cdot 2^{32} \cdot N_{block}$$

with

$$A = hashes\ expected\ to\ solve\ a\ block\ [h]$$

$$D_\mu = average\ block\ difficulty\ for\ the\ period$$

$$N_{block} = the\ number\ of\ blocks\ in\ the\ period$$

The network hashpower can be estimated by dividing the expected hashes by the number of seconds in the period.

$$H = \frac{A}{T_\Delta \cdot 86400}$$

with

$$H = hash\ power\ [h/s]$$

$$T_\Delta = time\ period\ blocks\ were\ mined\ (days)$$

T_Δ is multiplied by 86,400 to convert the period from days to seconds.

Equipment efficiency is the major unknown factor in calculating network consumption. For several years, equipment has been specifically designed to produce as many SHA256 hashes as fast and as efficiently as possible. Different efficiencies were selected for the upper and lower bound to represent the lowest and highest reasonable limits of network efficiency, respectively, for the period examined.

24 Database Dumps. (n.d.). Blockchair. Retrieved on July 14th, 2021 from https://blockchair.com/dumps - nodes

25 Difficulty. (November 19th, 2020). Bitcoinsv wiki. Retrieved on August 8th, 2021 from https://wiki.bitcoinsv.io/index.php/Difficulty

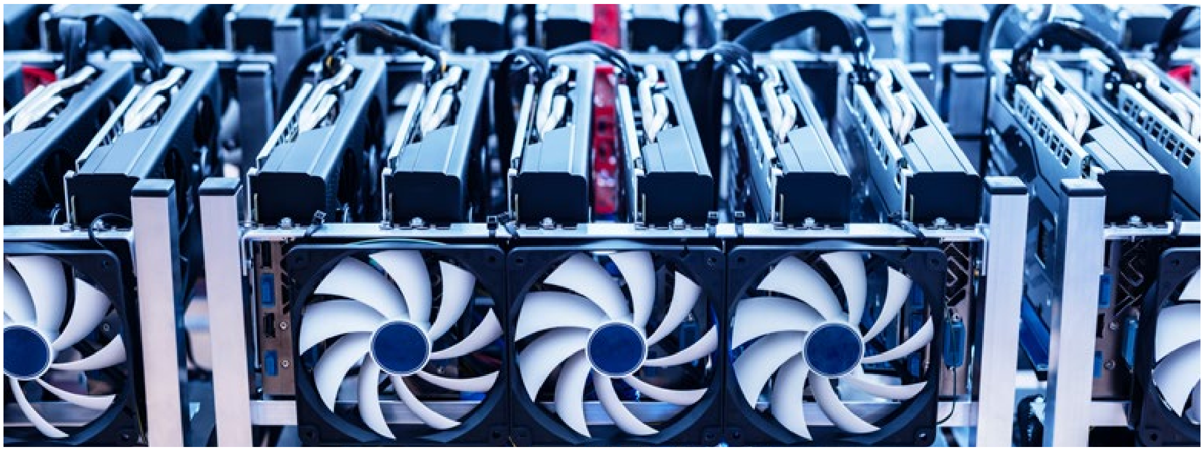
26 Difficulty. (July 28th, 2021). Bitcoin Wiki. Retrieved on August 8th, 2021 from https://en.bitcoin.it/wiki/Difficulty

Lower bound

In selecting the upper and lower bound, the market share data provided in the Stoll et Al[27] report was used to create a weighted average of the three miners from those manufacturers satisfying the upper and lower bound requirements. Based on the information in the sourced paper, it's reasonable to assume Bitmain's hardware makes up 78 percent of the equipment distribution, Ebang's 13 percent, and Canaan's the remaining nine percent. [28] This data was gathered from initial public offering filings along with other public filing documents. Further examination of public documents for Canadian operations found MicroBT hardware also makes up a large share of the market. This is validated by a February 2020 Coingeek article, estimating MicroBT's market share at up to 30 percent.[29] Without expanding this analysis further, this study was unable to incorporate these numbers at a global scale. While we did not account for MicroBT's influence in the upper and lower bounds, their equipment is included in our comparisons.

The lower bound of energy consumption assumes all equipment running on the network is the most efficient available at the time. The equipment available on or before June 13, 2021 was used. Selecting this date ensured no equipment could be more efficient based on equipment specifications, and, by extension, have a lower consumption. This choice also helps to offset techniques like over-clocking with immersion cooling, which miners use to improve the efficiency of their machines.

As of June 13, 2021, the most efficient miner available is the Bitmain S19 Pro. It has an efficiency of 29.5W/Th.[30] The Ebang Ebit E11++, and Canaan AvalonMiner 1246 were also selected. Together, with market share weighting applied, they produce an efficiency of 32.28 W/Th.



Upper bound

The upper bound of consumption utilizes equipment that is estimated to be the least profitable. The Hayes' equation for the miner's break-even point was used to determine what equipment is the least profitable. The equation calculates the minimum value of Bitcoin required for a machine to be profitable, based on the hashrate and efficiency of a miner, the number of Bitcoin in the block reward, and the difficulty of a block.

27 The Carbon Footprint of Bitcoin. (July 17th, 2019). Stoll et al. Retrieved from https://www.cell.com/joule/fulltext/S2542-4351(19)30255-7?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2542435119302557%3Fshowall%3Dtrue

28 Ibid

29 MicroBT market share rises as Bitmain's struggles continues. (February 24th, 2020). CoinGeek. Retrieved on August 8th, 2021 from https://coingeek.com/microbt-market-share-rises-as-bitmains-struggles-continues/

30 S19 Pro Specifications. (May 27th,2021). Bitmain Support. Retrieved on August 8th, 2021 from https://support.bitmain.com/hc/en-us/articles/900000261726-S19-Pro-Specifications

$$V_{Min} = \frac{V_{C\_day}}{R_d}$$

$$V_{c\_day} = (V_{KWh} \cdot 24 \cdot E_W)\left(\frac{H_{Gh}}{1000}\right)$$

$$R_d = \left(\frac{24}{3600}\right) \cdot \frac{2^{32}}{D} \cdot R_B \cdot H_{Th}$$

with

$$V_{Min} = Minimum\ value\ for\ bitcoin\ in\ the\ same\ currency\ as\ the\ price/\ KWh\ to\ be\ profitable$$

$$V_{c\_day} = The\ cost\ of\ running\ the\ miner\ for\ the\ day\ in\ the\ same\ currency\ as\ the\ price/KWh$$

$$R_d = The\ expected\ reward\ for\ the\ day$$

$$V_{KWh} = Price\ per\ KWh$$

$$E_w = Efficiency\ of\ the\ mining\ unit\ in\ W/Gh$$

$$H_{Gh} = Hash\ rate\ in\ Gh/s$$

$$H_{Th} = Hash\ rate\ in\ Th/s$$

$$D = Difficulty\ of\ the\ block$$

$$R_B = Reward\ per\ block\ in\ bitcoin$$

For the following estimations, the last block of BTC on June 13, 2021 is used. It had a difficulty of 19932791027263, a reward of 6.5 Bitcoin, and a value of 35666.15 USD per BTC.[31] The equation assumes a price per kWh of US$0.03 based on publicly available hydro rates provided by Hydro-Quebec.[32,33]

The three least efficient models, based on our calculations of expected miners' break-even point, following Hayes' methodology, were the Bitmain Antminer S9 (13 tera-hash version), Ebang Ebit E10, and Canaan AvalonMiner 921. When the market share weighting is applied, the upper bound efficiency estimate is 97.97 W/Th/s.

Key assumptions

The network is comprised of a mix of equipment. It is assumed the network is neither comprised of all the most efficient, nor all the least profitable. Our estimated equipment efficiency is selected to base the consumption estimate by taking an unbiased average of the equipment in the list (Appendix 1) between the upper and lower bounds — or higher efficiencies from manufacturers not represented in the market share weighting.

Consumption estimation

Our model determines network consumption at the indicated period by multiplying the network hashrate by the network efficiency by the time in the period.

$$C_N = E \cdot H \cdot T_\Delta \cdot 24$$

with

$$C_N = the\ consumption\ of\ the\ network\ over\ the\ period\ [KWh]$$

$$E = efficiency\ of\ equipment[KW/Th/s]$$

$$H = expected\ hash\ rate\ of\ the\ network\ [Th/s]$$

$$T_\Delta = time\ (days)$$

31 Bitcoin Price. (n.d.). YCharts. Retrieved on August 8th, 2021 from https://ycharts.com/indicators/bitcoin_price

32 2021 Electricity Rates (p. 85). (n.d.). Hydro-Quebec. Retrieved on August 8th, 2021 from https://www.hydroquebec.com/data/documents-donnees/pdf/electricity-rates.pdf#page=89

33 T. Reteurs. Quebec to maintain rates for digital currency miners, as demand grows. (April 29th, 2019). CBC News. Retrieved on August 8th, 2021 from https://www.cbc.ca/news/canada/montreal/quebec-to-maintain-rates-for-digital-currency-miners-as-demand-grows-1.5115933

Comparisons

Our estimate of the networks is compared with estimates derived from alternative equipment efficiencies.

Public documentation was gathered from miners operating in Canada. Using the numbers and types of equipment provided, a cumulative efficiency chart was created (Appendix 3) based on a weighted average. The weighting was based on the machine's proportional impact on the network. That is, the number of that type multiplied by its hashrate. Their documentation indicates these miners primarily produce work for BTC. The efficiencies were used to produce a consumption estimate that are compared with consumption estimate for BTC.

A large Canadian mining organization provided data on their BSV operations that was used to produce efficiency estimates. These estimates were used to produce consumption estimates that are compared against our consumption estimates for BSV.

Output value calculations

Our calculations measured the output for the three main metrics for each of the protocol chains, at both the miner and the network scopes: average consumption per block, average consumption per transaction validated, and average consumption per megabyte validated. In addition, the totals of blocks mined, transactions validated, and megabytes validated for each of the periods in the prior sections are summed.

$$C_{total} = \sum_{i}^{P} C_i$$

$$N_{totalBlocks} = \sum_{i}^{P} N_{block,i}$$

$$N_{totalTx} = \sum_{i}^{P} N_{tx,i}$$

$$N_{totalMb} = \sum_{i}^{P} N_{mb,i}$$

with

$$C_{total} = the\ total\ energy\ consumption\ over\ all\ periods\ [KWh]$$

$$N_{totalBlocks} = the\ total\ number\ of\ blocks\ over\ all\ periods$$

$$N_{totalTx} = the\ total\ number\ of\ transactions\ over\ all\ periods$$

$$N_{totalMb} = the\ total\ number\ of\ megabytes\ validated\ over\ all\ periods$$

$$P = the\ set\ of\ all\ periods$$

$$i = a\ period\ in\ P$$

$$C_i = The\ energy\ consumption\ for\ a\ period\ [KWh]$$

$$N_{block,i} = The\ number\ of\ blocks\ in\ the\ period\ covered\ by\ i$$

$$N_{tx,i} = The\ number\ of\ transactions\ in\ the\ period\ covered\ by\ i$$

$$N_{mb,i} = the\ number\ of\ megabytes\ validated\ in\ the\ period\ covered\ by\ i$$

The main metrics are calculated by dividing the total consumption by the total corresponding to the metric.

$$C_{avgBlock} = \frac{C_{total}}{N_{totalBlocks}}$$

$$C_{avgTx} = \frac{C_{total}}{N_{totalTx}}$$

$$C_{avgMb} = \frac{C_{total}}{N_{totalMb}}$$

with

$$C_{avgBlock} = average\ energy\ consumption\ per\ block\ [KWh/block]$$

$$C_{avgTx} = average\ energy\ consumption\ per\ tx\ [KWh/tx]$$

$$C_{avgMb} = average\ energy\ consumption\ per\ megabyte\ validated\ [KWh/MB]$$

Model results

Results indicate BTC consumes orders of magnitude more power than either of the other two protocols tested (Figure 1). The overall energy consumption difference is a function of the hashrate on the network (Figure 2), as illustrated by the proportional similarities in Figures 1 and 2. The estimated consumption difference between the protocol with the most consumption (BTC) and the protocol with the least consumption (BSV) is at its most (16041.24 GWh) in Q1 2021, and its least (11343.25GWh) in Q2 2020 as per our model's output. Our estimates indicate BTC consumes between 60 and 250 times the power of BSV per quarter.

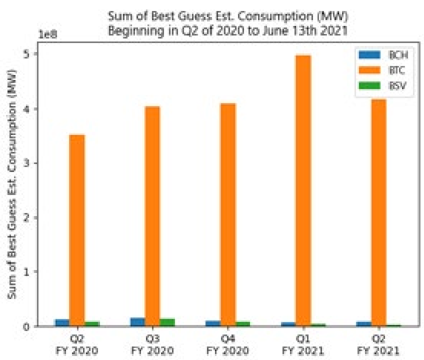


Figure 1

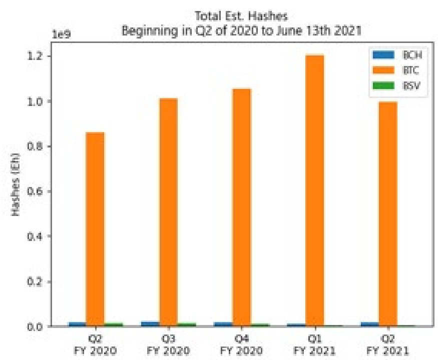


Figure 2

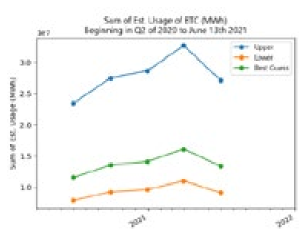


Figure 3(a)

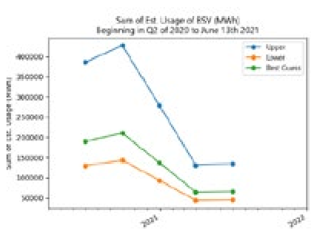


Figure 3(b)

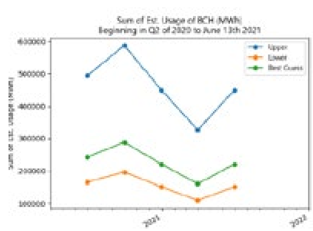


Figure 3(c)

Figures 3(a), 3(b), and 3(c) show a reasonable domain within which the actual consumption for each of the networks could exist. Our estimate exists within this domain. It is impractical to get an exhaustive distribution of active mining equipment, largely due to the decentralized nature of the networks.

The estimations of the boundaries and our estimates are based on the efficiencies of the equipment used to mine. The distinguishing factor between each of these network consumption estimates — as discussed in the modeling approach — is the difficulty of the network, and, by extension, the hashrate necessary to mine a block. Our estimates were consistently 23.5 percent between the lower and upper bound.

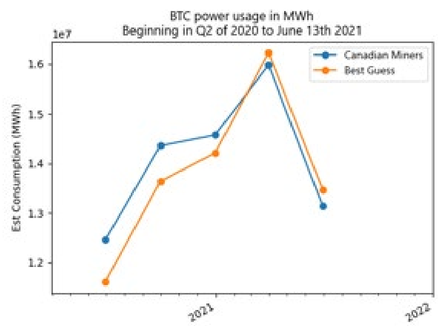


Figure 4

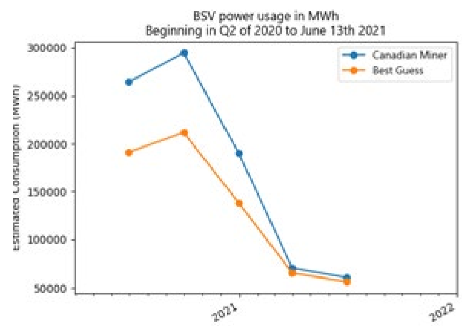


Figure 5

Figure 4 compares our estimates with a networkwide BTC energy efficiency estimate of Canadian miners' equipment compiled from public documents (Appendix 3). Our estimates for the network consumption deviate from the Canadian miners' estimate by 6.7 percent in Q2 2020, and as little as 1.5 percent in Q1 2021. Consumption from our estimate is lower in the first three quarters of the test period, and higher in the last two.

Similarly, Figure 5 compares an efficiency estimate based on data provided by a large mining firm operating in Canada against the BSV network. Our consumption estimate is as much as 28 percent above the actual miner data in Q3 2020 and down to 6.9 percent above in Q2 2021. Over the period, our estimate is consistently higher than the estimate based on actual miner data.

For BTC, the consumption per transaction steadily increases over time (Figure 6 (a)). The estimate beginning Q2 2020 has the average consumption at 430 kWh/tx through to 706 kWh/tx in Q2 2021. The estimated consumption per megabyte follows the same pattern, going from approximately 757 MWh/MB in Q2 2020 to 991 MWh/MB (Figure 7 (a)).

The estimated consumption per transaction peaks for BCH in Q3 2020 at 183 kWh/tx and falls as low as 6.5 kWh/tx in Q1 2021 (Figure 6). The estimated consumption per megabyte follows the same pattern, with a maximum of 194 MWh/MB in Q3 2020 and a minimum of 20.5MWh/MB in Q1 2021 (Figure 7).

The estimated consumption for both transaction and megabyte throughputs remains relatively consistent on BSV. The consumption per transaction ranges between 3.3 kWh/tx in Q3 2020 and 2.4 kWh/tx in Q2 (Figure 6). The consumption per megabyte 12.63 MWh/MB and 0.9 MWh/MB in Q2 2021 (Figure 7).

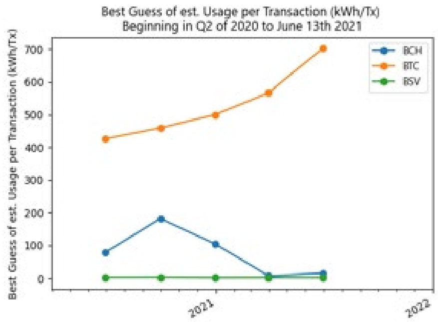


Figure 6 (a)

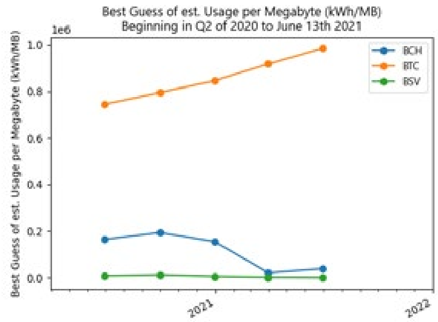


Figure 7 (a)

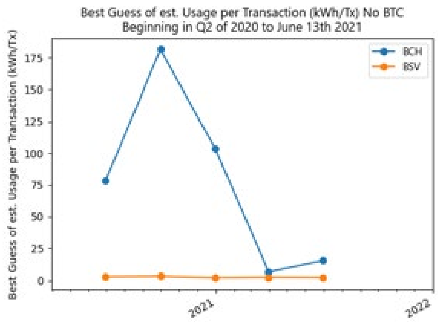


Figure 6 (b)

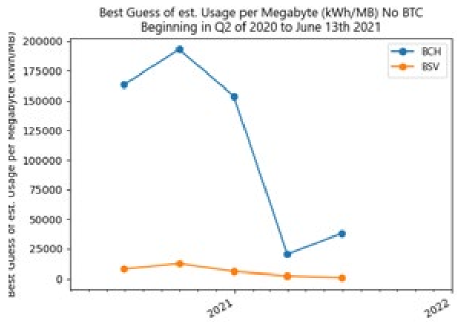


Figure 7 (b)

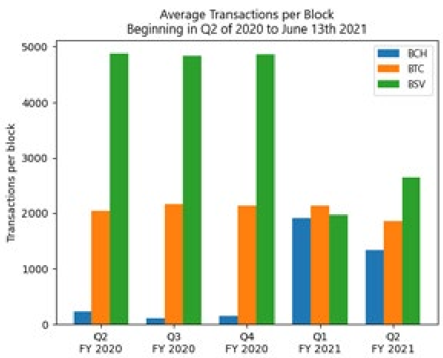


Figure 8

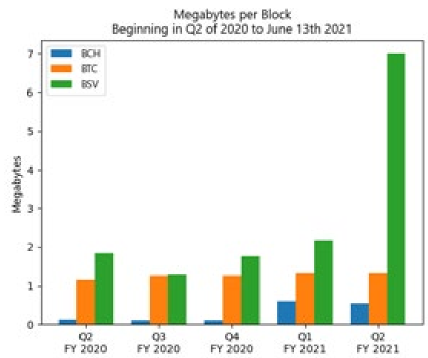


Figure 9

Conclusion

By leveraging real-world publicly available data, previous studies, and primary research, we have confirmed the validity of our model and assessment framework. Our model provides a reasonable estimate (accurate within 28 percent) when using Canadian cryptocurrency miner data provided to MNP. Although it is difficult to precisely measure the consumption of a decentralized network without making major assumptions regarding many of the variables, we were able to estimate using average power and performance characteristics specified by a sample of equipment manufacturers (see Appendix 1).

Our estimations were compared to estimations based on public data and shared proprietary data for two mining protocols, BTC and BSV respectively. There was a lack of data surrounding public miners of BCH to conduct a comparison of our model's estimates. The estimates were within 6.7 percent of the estimation based on public data for BTC and within 28 percent of the estimation based on proprietary data for BSV.

As can be seen in the model results section, the consumption estimates become more representative near the end of the tested period. This may be because the calculations were performed based on variables on the last day of the sample period. Similarly, the greater discrepancy in observed accuracy between the BTC and BSV tests may be due to the estimated efficiency being based on the profitability of BTC. To improve the accuracy of this methodology in the future, it would be advisable to make these profitability calculations at multiple stages throughout the test period and for each of the protocols being tested.

The three Bitcoin protocols, BTC, BSV, and BCH, were compared to see which was more efficient. Given that all Bitcoin protocols are subject to the mining difficulty being affected by the computational potential of the miners on them, the metrics for efficiency were kilowatt-hours per transaction and kilowatt-hours per megabyte validated. These illuminate the major distinctions between the protocols.

When looking at the throughputs for the various networks, it is possible to see the potential capacity differences having a large effect on efficiency. The power consumption per transaction, and equally, per megabyte, decreases when network utilization is higher on more protocols with a more permissive block size than on those that are more restrictive. The arbitrary limitations of BTC and BCH may have a significant impact on the power consumption per transaction.

If the same BSV transaction counts are applied to our consumption estimates of BTC for the first three quarters, where the difference in transaction count per block is most clear, the consumption per transaction would be reduced to between 181 and 221 kWh/tx — as in the last three quarters of 2020. That is a reduction of 57 to 55 percent respectively for the same periods. With greater utilization and throughput, these reductions in consumption per transaction and increase in efficiency will only improve.

BSV is more efficient due to block size and number of transactions (throughput) currently available on the network and limitations of other protocols. So long as the size or number of transactions on the BSV network exceeds the limitation of the other protocols, BSV is the most efficient in this group.

Appendix 1 – Mining equipment

Equipment specific information was gathered from suppliers' and manufacturers' publicly available data and information sheets, and was accessed through the month of June 2021.

Miner name	Hashing power (Th/s)	Power (W)	Efficiency (J/Th)	Sources
Bitmain Antminer T17+	64	3,520	50	Bitmain Support
Bitmain Antminer S19 Pro (110T)	110	3250	29.5	Bitmain Support
Bitmain Antminer S19	95	3250	34	Bitmain Support
Bitmain Antminer S9(13TH)	13	1274w	100	Bitmain Support
Bitmain Antminer S9j (14TH)	14	1400	96	Bitmain Support
Ebang Ebit E10	18	1650	92	ASIC Miner Value; EBIT E10.1 18TH/S sold out - Ebit - Ebit Miner (ebang.com.cn)
Canaan AvalonMiner 1246	90	3420	38	AvalonMiner 1246 (canaan.io)
Canaan AvalonMiner 921	20	1800	89	ASIC Miner Value; Avalon 921 20.0TH/s ASIC Miner | bitnand
Bitmain Antminer S17+	67	2680	40	Bitmain Support
Canaan AvalonMiner 1066 Pro	50	3300	60	AvalonMiner 1066 Pro (canaan.io)
Ebang Ebit E12+	50	2500	50	Miner Ebang
MicroBT Whatsminer M31S	74	3312	46	Whatsminer
StrongU STU-U8	46	2200	51.2	StrongUtech
Ebang Ebit E11++	44	1980	45	Miner Ebang
Bitmain Antminer S17 (50Th)	50	2250	42	Bitmain Support
Bitmain Antminer S17 (53Th)	53	2385	45	Bitmain Support
Bitmain Antminer S17e	56	2520	45	Bitmain Support
StrongU Hornbill H8	74	3330	45	ASIC Miner Value; Mining Watch-dog
ASICminer 8 Nano S 58Th	58	2500	44	Miners Depo.com
Innosilicon T3+ 52T	52	2200	42	Sale-toolshop
Canaan AvalonMiner 1166 Pro	81	3400	42	AvalonMiner 1166 Pro (canaan.io)
Bitmain Antminer S17 Pro (53Th)	53	2094	39.5	Support Bitmain
Bitmain Antminer S17 Pro (50Th)	50	1975	39.5	Support Bitmain

Miner name	Hashing power (Th/s)	Power (W)	Efficiency (J/Th)	Sources
MicroBT Whatsminer M30S	88	3344	38	Whatsminer
Canaan AvalonMiner 1246	90	3420	38	AvalonMiner 1246 (canaan.io)
Bitmain Antminer T19 (84Th)	84	3150	37.5	Bitmain Support
Bitmain Antminer S19j	94	3243	34.5	Bitmain Support
MicroBT Whatsminer M30S+	100	3400	34	Whatsminer
MicroBT Whatsminer M30S++	112	3472	31	Whatsminer
Bitmain Antminer S19j Pro	104	3068	29.5	Support Bitmain

Appendix 2 – Canadian miners surveyed

Company	Province	Coins Mined	Energy source	Capacity (MW)
Bitfarms	QC	BTC	Hydro	10
Bitfarms	QC	BTC	Hyrdo	15
Bitfarms	QC	BTC	Hyrdo	4
Bitfarms	QC	BTC	Hydro	10
Bitfarms	QC	BTC	Hyrdo	30
Hut8	AB	BTC	Gas, Wind, Solar	67
Hut8	AB	BTC	Gas, Wind, Solar	43
Hive Blockchain Technologies LTD	QC	BTC	Hyrdo	30
Blockstream	QC	NA	NA	NA
DMG	BC	BTC	Hydro	Minimum 80
argo	QC	BTC, Zcash	Mainly Hydro	15
argo	QC	BTC, Zcash	Mainly Hydro	5
Ocean Falls Blockchain	BC	BTC, ETH	Hyrdo	NA
MAAS Blockchain	BC	NA	Hydro	NA
Miningsky	BC	BTC, ETH	Conventional Grid at Location	Minimum 8
Miningsky	QC	BTC, ETH	Conventional Grid at Location	Minimum 8
Miningsky	MB	BTC, ETH	Conventional Grid at Location	Minimum 8
Plexus	AB	NA	Gas	15
ADMCO	AB	NA	NA	NA
Quotecolo	AB	NA	Gas	3x10 max

Appendix 3 – Canadian miner equipment

Period	Company	Machine model	Miners deployed	TH/unit	Efficiency
Q3 2019	BitFarms	T3	4100	50	0.062
Q3 2019	BitFarms	A1047	2500	37	0.0625
Q3 2019	Argo	S17	1809	53	0.045
Q3 2019	Argo	T17	1000	40	0.055
Q4 2019	BitFarms	M20S	2250	68	0.0494
Q4 2019	Argo	T17	500	40	0.055
Q4 2019	Argo	S17	500	53	0.045
Q2 2020	DMG	M30S	1500	88	0.038
Q3 2020	BitFarms	M31S+	1000	80	0.042
Q4 2020	BitFarms	M31S	2000	72	0.044
Q4 2020	BitFarms	M31S	1000	74	0.046
Q1 2021	BitFarms	M31S+	4500	80	0.042
Q2 2021	BitFarms	M31S+	1500	80	0.042

Canadian miner estimated efficiencies

	Avg. equipment efficiency (KW/Th)
Q3 2019	0.05769968
Q4 2019	0.05507613
Q1 2020	0.05507613
Q2 2020	0.05212919
Q3 2020	0.05117007
Q4 2020	0.04983871
Q1 2021	0.04785545
Q2 2021	0.04740003

Appendix 4 – Assumptions framework

Assumption	How we got here	Source(s)
Energy consumption	Energy consumption is best measured in watt-hours per block. Miners are exclusively competing to validate new blocks — therefore, all efforts are directed to validating new blocks. Energy consumption is dependent on equipment efficiency and the current block difficulty. Block difficulty sets the time it takes to validate one block. Equipment efficiency is the amount of power per hash rate of the mining equipment (e.g., j/Mh or j/Th).	O'Dwyer et al Hayes Zade et al de Vries Stoll et al
Block difficulty	Block difficulty is set every 2,016 blocks so that the average block time is 10 minutes (or two weeks). These are protocol-based rules. Block difficulty can be used to calculate the implied total network hash rate. Block difficulty varies depending on the number of active miners contributing hash rate as well at other factors (e.g., current price).	Direct observations from Data Literature: O'Dwyer et al Hayes Zade et al de Vries Stoll et al
Average block time	Average block time is used to calculate set the block difficulty. This fluctuates over time with new nodes entering and exiting the network. The target for block time is 10 minutes.	O'Dwyer et al Hayes Zade et al de Vries Stoll et al
Network hash rate	The network hash rate is dependent on the total number of miners contributing to the overall hash-rate of the network.	O'Dwyer et al Hayes Zade et al de Vries Stoll et al
Number of miners	The number of miners is not directly observable. Not all nodes will mine. Several papers split miners into categories based on hashrate contribution. Miners enter and exit the network based on profit-ability factors. Miners choose mining equipment based on a set of preferences and economics (assumption of rational actors).	O'Dwyer et al Hayes Zade et al de Vries Stoll et al

About MNP

MNP is a leading national accounting, tax and business consulting firm in Canada. We proudly serve and respond to the needs of our clients in the public, private and not-for-profit sectors. Through partner-led engagements, we provide a collaborative, cost-effective approach to doing business and personalized strategies to help organizations succeed across the country and around the world.

PRAXITY™ Empowering Business Globally