ELECTRIC POWER RESEARCH INSTITUTE

Quick Insights

Bitcoin Mining, Blockchain, and Electricity Consumption

RESEARCH QUESTION

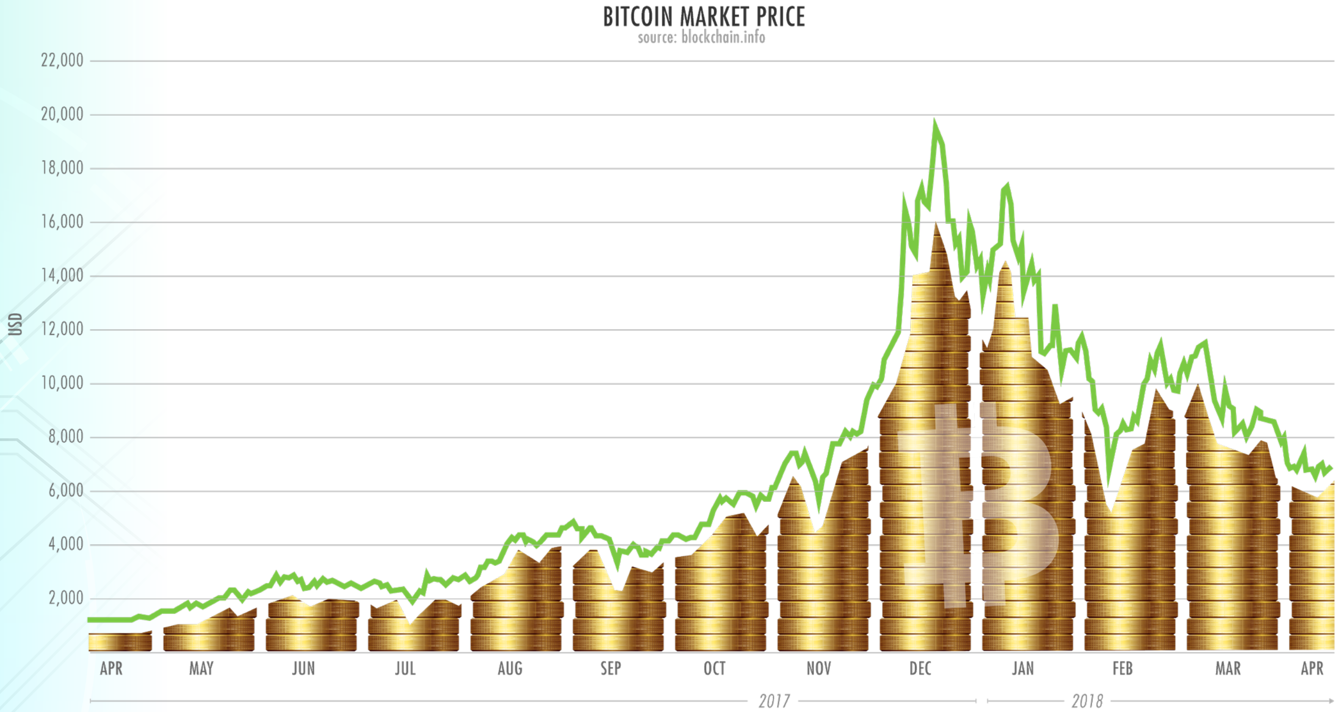
What is the energy consumption of mining cryptocurrencies such as Bitcoin, and how can utilities best interact with these customers?

INTRODUCTION

In 2009, Bitcoin became the first digital currency based on cryptography—creating what has become broadly known as *crypto-currencies*—to provide a medium of currency exchange without a central authority and without backing by a physical commodity or nation-state. There are currently more than 1,300 similar cryptocurrencies using cryptography to secure transactions, control the creation of new currency, and validate the transfer of value. Cryptocurrencies are backed by blockchain technology, which employs cryptography to validate each transaction and create a permanent public record. Bitcoin mining requires large amounts of electricity, but its inherent volatility, decentralized operations, and uncertain future create challenges for electric utilities engaged in long-term resource planning.

KEY POINTS

- Bitcoin mining requires an estimated 1 to 3 GW of continuous electricity demand—representing less than 0.1% of global electricity generation capacity.
- It is difficult to determine the actual electricity use for mining Bitcoin at any given time because there is no central registry of miners. Similarly, it is virtually impossible to accurately predict future growth because the efficiency of mining equipment is changing rapidly, the difficulty of mining varies, and the revenue paid to miners is highly volatile.
- Given that the values of many cryptocurrencies have recently skyrocketed, any reporting that extrapolates current growth rates to project future electricity demand will likely inflate future predictions of consumption.
- The potential boom-bust nature of cryptocurrency mining and the risk of failure for this emerging industry may present a risk to electric utility cost-recovery or lead to stranded assets.
- Amid rapid Bitcoin mining growth in U.S. regions where electricity is inexpensive, local utilities have grappled with accommodating or banning this type of electricity load.
- The blockchain technology that underpins cryptocurrencies could eventually streamline the management of other transactive processes, but it is too soon to determine its ultimate impact.



WHAT IS BLOCKCHAIN?

Fundamentally, a blockchain is a series of digital blocks, each of which contains a set of transactions. A unique identifier represents the contents of each block and the combined value of all prior blocks in the chain. This linkage of unique identifiers, called a "cryptographic hash," ties the blocks together in the chain. Rather than having a centrally stored and controlled ledger like a traditional accounting system, the blockchain's "ledger" is distributed, with each participant in the peer-to-peer network holding a copy of the "distributed ledger."

Each *block* of transactions recorded in a blockchain requires a proof of work (PoW) to validate the block and securely append (and timestamp) it to the ledger. This creates a chain of blocks, hence the name blockchain.

A PoW is a cryptographic hash discovered by performing a computationally intense algorithm called *mining*. A hash function is simple to compute given an input value, but the inverse function—i.e. solving for an input given the output—can only be determined through brute-force trial and error. Because a PoW is required to validate each block of transactions that is added to the ledger, mining is necessary to support the use of the currency. In exchange for computing the hash, a miner earns a reward (typically a small amount of the cryptocurrency).

For more information on potential applications for blockchain technology, see EPRI Quick Insight 3002009889 [1] and EPRI white paper 3002010242 [2], which explain how blockchain technology could be applied to other utility transactional business operations.

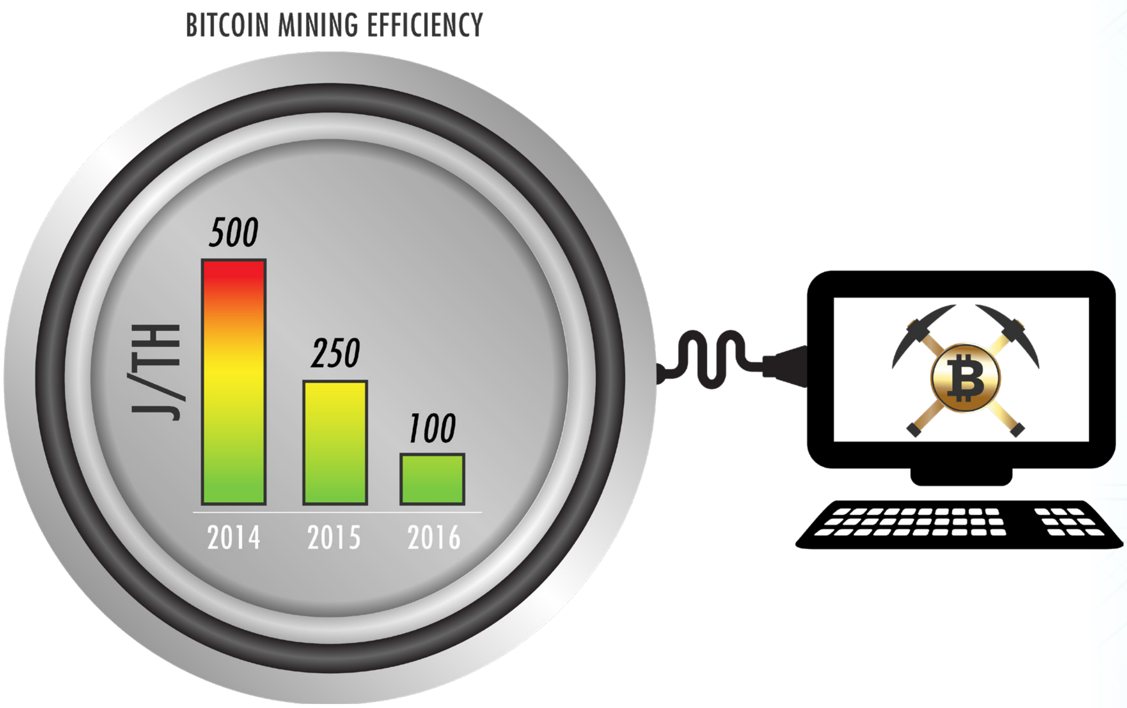
MINING FOR CRYPTOCURRENCY

When Bitcoin was first established, mining was possible using the CPU of a standard desktop PC. As more miners have joined the Bitcoin network, the global *hash rate* (overall number of hash functions that are solved by all miners on the network, now represented by exa hashes per second [EH/s, 10^{18} H/s]) has risen exponentially, to as high as 26 EH/s in March 2018.

The difficulty of the mining algorithm is adjusted roughly every 10 days to maintain an average creation of one block every 10 minutes. With the mining reward set to be halved about every four years, mining will become less profitable over time. As a result of continuously growing resource requirements—particularly the amount of electricity needed for processing and cooling—CPUs are no longer cost-competitive for Bitcoin mining. To improve efficiency, miners initially shifted from CPUs to graphics processing units (GPUs), which offer about an order of magnitude superior mining performance over standard CPUs.

Today's best-in-class mining hardware—which employs an application-specific integrated circuit (ASIC) specially designed for mining Bitcoin—performs two orders of magnitude better than GPUs. Due to advances in chip technology, reported mining efficiencies have roughly doubled every 12 months, from about 500 J/TH (joules per terahash, equivalent to watts per trillion hashes per second) in late 2014, to 250 J/TH in late 2015, to 100 J/TH in mid-2016. Recognizing that one of the largest manufacturers of mining hardware also operates one of the world's largest mining facilities, there may be preproduction mining machines in operation that surpass the commercially available 100 J/TH efficiency level.

Serious Bitcoin mining operations are not expected to reside in conventional data centers because the core business of data centers that house mining operations is to maximize the number of hashes computed for the lowest operating cost. With little concern for equipment availability, mining facilities do not employ the redundancy, fault-tolerance, or power conditioning equipment used in conventional data centers. In addition, many miners use "free cooling," relying on evaporative "swamp" cooling rather than mechanical (vapor compression) cooling. Some mining facilities have no mechanical cooling aside from fans that bring in outdoor air.

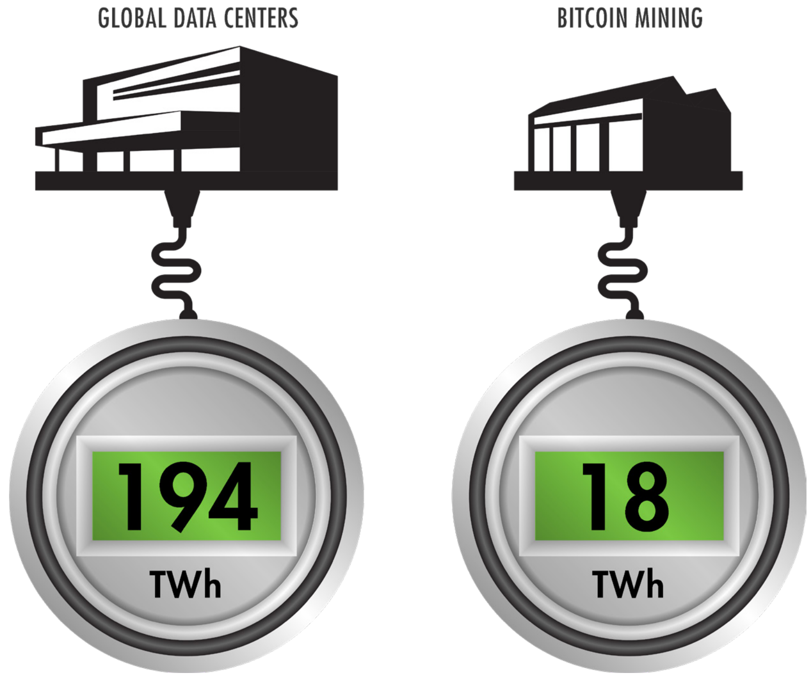


INDUSTRY ENERGY CONSUMPTION

Since December 2017, when the value of Bitcoin reached an all-time high of $20,000 per bitcoin, numerous media outlets have reported on the growing energy consumption of the Bitcoin network. These reports cite the Bitcoin Energy Consumption Index (BECI) published on Digiconomist.net [3] which uses an economic approach to estimate the annual energy consumption of Bitcoin (more than 50 TWh as of March 2018). Note that any estimate of overall energy consumption must make numerous assumptions because there is no central registry of all active Bitcoin mining machines. Moreover, there is neither published data on the efficiency of mining machines in real-world applications, nor data on the number of machines in operation.

However, this widely cited estimate is fundamentally flawed; it assumes that 60% of mining revenue is spent on electricity, without providing a citation. One critic of this approach [5] suggests that the actual percentage of mining revenue spent on electricity may range from 6% to 32%, when accounting for capital recovery. In addition, the author of the BECI estimate presents a case study from an operating mining facility that found that the real-world efficiency of mining machines was less than rated efficiency—a finding attributed to the elevated operating temperature and failure rates seen in the real-world application.

Marc Bevand, a cryptocurrency researcher and entrepreneur, makes a more detailed evaluation of hardware efficiency on his website [4]. This approach took an in-depth look at the evolution of mining hardware efficiency over time, estimating the number of machines added in each hardware generation as a function of the increasing global hash rate. It makes the conservative estimate that only the least-efficient hardware available in each generation was added, so long as it was profitable to operate at $0.05/kWh. On January 11, 2018, Bevand updated his estimate of the global Bitcoin mining network to be 2.1 GW of demand (upper and lower bounds of 1.6 and 3.1 GW) and 18 TWh of annual consumption (bounded by 14 and 27 TWh).



The results of this estimate and others suggest that Bitcoin mining worldwide is on the order of 2 to 3 GW. With global installed generating capacity totaling more than 6,200 GW as of 2015 [6], Bitcoin mining represents less than 0.1% of world generating capacity. In 2014, the annual energy consumption of data centers worldwide was estimated to be 194 TWh [7], roughly 10 times the annual consumption of Bitcoin mining estimated by Bevand [4].

There may be valid concerns as to how the energy intensity of cryptocurrencies would scale if they were to handle the number of transactions supported by credit cards each year (roughly two orders of magnitude more). Any reporting that extrapolates current growth rates—when the value of the currency has recently skyrocketed—will likely inflate future predictions of energy consumption. It is virtually impossible to make an accurate prediction of growth in mining demand due to the number of unknown variables, including:

- Mining difficulty depends on the number of miners connected;
- The real-world efficiency of mining hardware is unknown, and reported hardware efficiency has improved at an unprecedented rate;
- The revenue paid to miners is highly unpredictable because it is determined by the value of the cryptocurrency, which has been highly volatile.

EVOLVING INDUSTRY

While it is impossible to predict the rate of future mining growth, there is evidence that this industry may continue to expand in the near future. First, demand for mining equipment has created a scarcity of best-in-class hardware, and prices have risen significantly. In addition, anecdotal reports from mining operations and utilities indicate that it is growing rapidly in certain parts of the United States.

Previously, the majority of commercial Bitcoin mining operations have been located in China—specifically, Inner Mongolia—due to its cool, dry climate and reportedly low cost of electricity. In January 2018, the Chinese government began to curb mining, in part due to its impact on demand for electricity. Since then, there have been several reports on mining operations seeking to make significant expansions in areas of North America where electricity and land prices are modest and the climate favors free cooling. For example, mining operations in Wenatchee, WA have been able to take advantage of low-cost electricity and unused distribution capacity left by shuttered industries (namely aluminum and logging). On the other hand, Plattsburgh, NY has banned any additional mining operations from locating there for 18 months due to the impact that these facilities may have on local electricity prices.

Even with low-cost electricity, the volatility of mining revenues may drive some mining companies to cease operations before electric utilities fully recover the costs of delivering service. With so much uncertainty in the longevity of this market, utilities may best consider these customers cautiously. Yet given the high load factor of these facilities, some utilities might consider them very attractive customers, if only for a limited time.

One aspect largely missed in the discussion of blockchain efficiency is the potential for the technology to make other transactive processes more efficient. Because blockchain eliminates the need for a central database manager or independent transaction validator, it could streamline transaction management in areas other than cryptocurrency. If used for transactional databases in other industries (e.g. the insurance, medical, real estate, and banking sectors), Blockchain technology has the potential to offer global (societal) efficiency gains (i.e. digitizing and streamlining the management of verified transactions) while increasing electricity use to validate the transactions. However, it is too early in the maturity of this technology and its deployment to predict the potential efficiency gains. This is an area of continuing research that EPRI is conducting under its Information and Communications Technology for Integration of Distributed Energy Resources program [8].

RESEARCH GAPS

- Can the actual energy consumption of cryptocurrency mining be more accurately estimated? What is the real-world efficiency of deployed mining machines?
- What is the risk to an electric utility of stranded assets or failure to recover costs?
- Can a mining operation follow time-of-use rates and only be active during periods of low electricity prices?
- Are there methods for making cryptocurrencies more efficient while maintaining security and validity?
- Can blockchain technology offer global (societal) efficiency gains (i.e. digitizing and streamlining the management of verified transactions)?
- What electric utility or other industry processes are best suited to blockchain technology?

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