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Tracking electricity consumption from U.S. cryptocurrency mining operations

Summary

Electricity demand associated with U.S. cryptocurrency mining operations in the United States has grown very rapidly over the last several years. Our preliminary estimates suggest that annual electricity use from cryptocurrency mining probably represents from 0.6% to 2.3% of U.S. electricity consumption. [1]

This additional electricity use has drawn the attention of policymakers and grid planners concerned about its effects on cost, reliability, and emissions. Key challenges associated with tracking cryptocurrency mining energy use include the difficulty of identifying cryptocurrency mining activity among millions of U.S. end-use customers and the dynamic nature of the crypto market, where mining assets can be moved rapidly to areas with lower electricity prices.

We have developed general estimates of electricity use by U.S. cryptocurrency mining operations by employing both top-down and bottom-up approaches. Our top-down approach involves data from the Cambridge Centre for Alternative Finance, which maintains an index that estimates global and national electricity use from cryptocurrency activities. We also developed our own bottom-up approach, which involves collecting data pertaining to the location of individual cryptocurrency mining operations and the amount of electricity each facility says it may use.

In order to develop more rigorous estimates of electricity use by U.S. cryptocurrency miners, we have requested and received an emergency clearance pursuant to Office of Management and Budget (OMB) procedures established at 5 CFR Part 1320, Controlling Paperwork Burdens on the Public.[2] We plan to begin collecting data on a monthly basis from February through July 2024.

Interest in cryptocurrency mining

Although cryptocurrency mining began in the United States about a decade ago, the activity began to expand rapidly in 2019. Recent growth is largely due to cryptocurrency mining operations relocating to the United States from China after that country cracked down on digital currency mining in 2021, though reports indicate that there may still be some mining in China.[3] As cryptocurrency mining has increased in the United States, concerns have grown about the energy-intensive nature of the business and its effects on the U.S. electric power industry. Concerns expressed to EIA include strains to the electricity grid during periods of peak demand, the potential for higher electricity prices, as well as effects on energy-related carbon dioxide (CO_2) emissions.

For example, several members of Congress in letters to the U.S. Secretary of Energy in November 2022[4] and February 2023[5] outlined their desire to secure information that could better identify the effects of cryptocurrency mining on electricity and energy-related CO_2 emissions. In those letters, the members of Congress emphasized the need for the development of a “mandatory disclosure regime” regarding emissions and energy use by cryptocurrency miners.

Grid planners have also begun to express concern over the rapid growth in electricity demand associated with cryptocurrency mining. For example, the North American Electric Reliability Corporation (NERC) indicates in its latest long-term reliability assessment that “due to unique characteristics of the operations associated with cryptocurrency mining, potential growth can have a significant effect on demand and resource projections as well as system operations.”[6] As evidence, the Electric Reliability Council of Texas (ERCOT) has 41 gigawatts (GW) of requests for new cryptocurrency mining capacity, for which 9 GW of planning studies have been approved, according to NERC.

Electricity use and cryptocurrency mining

Several cryptocurrencies, most notably Bitcoin, use a *proof of work* approach to releasing new cryptocurrency. Creating cryptocurrency through proof of work is known as *mining*. Cryptocurrency miners add blocks of transactions to a blockchain by solving complex cryptographic puzzles that require significant computational power. The blockchain represents a digital ledger that allows participants to track transactions across the cryptocurrency network. In exchange for adding blocks to the blockchain, miners are rewarded with transaction fees and new cryptocurrency coins.

Not all cryptocurrencies use proof of work to generate cryptocurrency. Other cryptocurrencies, most notably Ethereum, use another process known as *proof of stake*. To validate transactions and add new blocks to the blockchain, participants stake a portion of the blockchain’s native tokens as collateral. These validators are rewarded if the transaction is completed successfully or penalized if attempting to perform illegitimate activity. Because it is not based on extensive computational effort, proof of stake cryptocurrencies use significantly less computing power, and so less electricity, than proof of work cryptocurrencies. According to data from the Cambridge Centre for Alternative Finance, Ethereum represents 0.005% of the power demand of Bitcoin, largely because of its different consensus mechanism.

Investors in proof of work cryptocurrency mining make use of specialized hardware that can perform many trillions of calculations a second. The computational power of a network mining cryptocurrency is measured as a *hash rate*, which represents the number of guesses or attempts to solve the cryptographic puzzle per second.

Larger networks of mining units can be configured to increase the computational power. One way to assess the size of a network is the number of and type of mining units at each site. Individual cryptocurrency facilities we identified can employ 10,000 to 20,000 mining units, although the largest facilities are known to have as many as 100,000 mining units in operation. Because these networks consist of modular units, operators can relocate their equipment so long as they can construct facilities that protect and control the climate of the networked mining units. Mining units are often stacked in containers for relatively quick and economical transport.

The primary operating cost of a cryptocurrency mining facility is expenditure for electricity. The computational effort needed to support profitable cryptocurrency mining consumes large amounts of electricity to operate the machines as well as to cool equipment to prevent overheating. Consequently, owners are constantly seeking various alternatives to acquire substantial amounts of power at the lowest possible cost.

Cryptocurrency mining facilities have made use of a variety of strategies to manage their electricity cost by reducing their consumption and the price paid for electricity. The computational efficiency, measured in joules per terahash, has steadily improved over time. However, this improved efficiency is countered by the generally increasing difficulty of the cryptographic puzzles that must be solved to append new blocks to the blockchain. To minimize the price paid for electricity, some cryptocurrency miners have located their facilities using several different strategies:

- Near existing and underutilized power plants or from suppliers of electric power that operate low-cost generators such as large hydroelectric dams
- With direct connection to a power generating source, avoiding costs associated with connecting to a legacy electric transmission or distribution company (for example, a new cryptocurrency mining operation located in Pennsylvania receives its electric power directly from an adjacent nuclear power plant)
- On sites that can make use of very low-cost or stranded energy sources, including adjacent to natural gas wells that have waste methane that would otherwise need to be flared

In the past, cryptocurrency mining access to these low-cost sources of electricity could not always be maintained, prompting facilities to relocate. Operators have also relocated facilities to gain access to a larger share of renewable energy, such as adjacent to a wind farm.

The increased demand associated with cryptocurrency mining can present challenges to the operation of electricity grids. After some early problems where electricity prices spiked due to a sudden surge in cryptocurrency mining, wholesale and retail markets have been able to make adjustments to handle the new load. Some grid operators have instituted programs that provide incentives for large electricity consumers to curtail their use during periods of peak demand. Cryptocurrency miners have become regular participants in these programs, known as demand-response, resulting in operations being cut back or shut down temporarily. In addition, cryptocurrency miners in areas with fluctuating power prices have reduced their electricity use in response to periods of high prices in wholesale power markets, given the sensitivity of their operational profitability to electricity prices.

For example, in Texas, the grid operator ERCOT has created its Large Flexible Load (LFL) program, which enlisted up to 1,530 megawatts (MW) of large industrial consumers to curtail their use during peak demand periods. Cryptocurrency miners are major participants in the LFL program, which also requires plant owners to inform the state of anticipated demand for electricity over a future five-year period. For example, operators of two large cryptocurrency mining facilities, located at the site of a former aluminum smelter in Rockdale, Texas, estimate that each can require up to 500 MW of electric capacity.

Methods for estimating energy use in cryptocurrency mining

Developing more information about cryptocurrency mining in the United States and its effects on electricity demand is important to provide context for energy policymakers, energy planners, and the general public. However, assessing the electricity use of cryptocurrency miners is difficult for several reasons. First, cryptocurrency mining can be performed with facilities of many sizes, ranging from individual workstations to massive data centers, which makes identifying them among the millions of end-use customers in the United States difficult. Second, identifying and tracking cryptocurrency mining facilities is made more difficult by the propensity of these operations to move in search of lower cost electricity. Third, when a cryptocurrency mining operation is identified, information on its power draw and operations is often unavailable or unclearly specified. Varied facility sizes, a paucity of data on operations, and shifts in facility location and ownership add complexity to the creation of a statistically representative sample of cryptocurrency miners.

In order to explore more fully the possibility of developing better information given these challenges, we recently submitted an Emergency Revision Request to OMB, which it approved on January 26, 2024. We expect to be able to publish more detailed information about cryptocurrency mining use of electricity in the United States with newly acquired data in mid- to late 2024.

A top-down approach to determine crypto-mining electricity usage

The Cambridge Bitcoin Electricity Consumption Index (CBECI)[7], published by the Cambridge Centre for Alternative Finance,[8] provides estimates of power demand from operations mining for Bitcoin and Ethereum on a daily and annual basis. Using CBECI estimates, we can approximate the Bitcoin-related electricity demand in the United States.

The methodology used in the CBECI is based on a hybrid top-down approach that builds a basket of real-world hardware, which represents a typical mining unit, with an underlying assumption that mining participants awarded Bitcoin are rational economic agents.[9]

The CBECI daily and annual estimates include lower and upper theoretical bounds and an estimated amount using best-guess assumptions. The inclusion of these bounds reflects the inherent uncertainty in their estimates. The index is updated every 24 hours because cryptocurrency miners ramp up or down their activities in response to price fluctuations and the availability of mining equipment, so electricity use can change quickly. The CBECI's estimated range of Bitcoin mining power demand at the end of January 2024 was quite wide, with an estimate of 19.0 GW and lower and upper bounds of 9.1 GW and 44.0 GW, respectively. Multiplying these average power demands by the hours in a year yields total annual electricity demand: 80 terawatthours (TWh) (lower bound), 170 TWh (estimate), and 390 TWh (upper bound).

The CBECI estimates that global electricity usage associated with Bitcoin mining ranged from 67 TWh to 240 TWh in 2023, with a point estimate of 120 TWh. The International Energy Agency estimated global consumption of electricity during 2023 to have been 27,400 TWh.[10] So, the CBECI estimates put electricity supporting Bitcoin mining in 2023 at about 0.2% to 0.9% of global demand for electricity. Based on those estimates, global electricity use in cryptocurrency mining was about the same as total electricity consumption in Greece or Australia, respectively.[11]

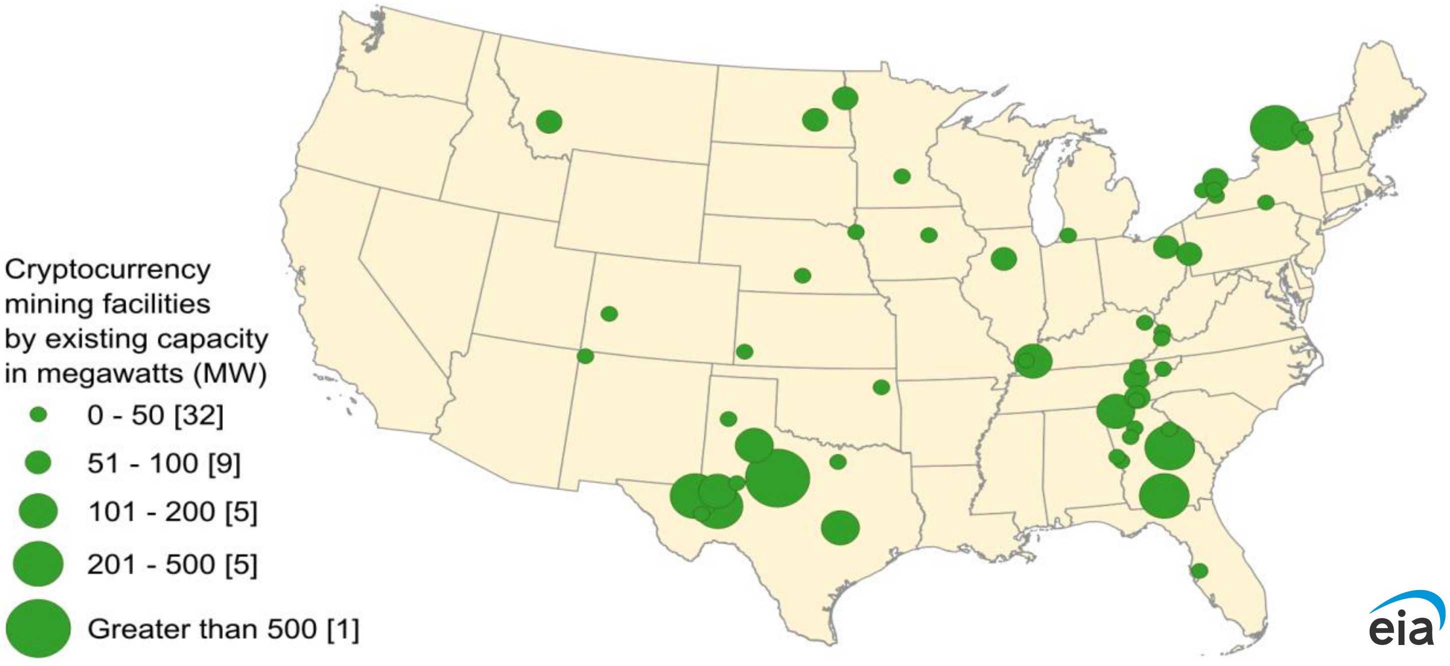
The CBECI also tracks the geographic distribution of Bitcoin mining, enabling the estimation of electricity use in different countries. The CBECI estimates that the global share of Bitcoin mining occurring in the United States rose from 3.4% in January 2020 to 37.8% in January 2022, the last month for which published estimates are available.[12]

Assuming the share of global activity in the United States remains approximately 38%, we estimate electricity usage from Bitcoin mining based in the United States to range from 25 TWh to 91 TWh. That estimate represents 0.6% to 2.3% of all United States electricity demand in 2023, which was 3,900 TWh.[13] This estimate of U.S. electricity demand supporting cryptocurrency mining would equal annual demand ranging from more than three million to more than six million homes.[14] The low end of the range would equal annual electricity usage for entire states such as Utah and West Virginia, among others.[15] Note that the CBECI-based estimates provided here are only based on Bitcoin and do not include other proof of work cryptocurrencies.

A bottom-up approach to determine crypto-mining electricity usage

Another approach to estimating cryptocurrency mining's effects on electricity use in the United States is to build up an estimate from what we know about individual facilities. To that end, we have worked to identify as many U.S. cryptocurrency mining facilities as possible. We have identified a total of 137 facilities to date; the 52 facilities for which we have location and capacity data are represented in Figure 1. These sites are located in 21 states, with most in Texas, Georgia, and New York.

Locations of 52 U.S. cryptocurrency mining operations, as of January 2024



Data source: U.S. Energy Information Administration
Note: The representative size shown for a facility is based upon estimates contained in our bottom-up approach. Number in brackets represents the number of facilities.

To assemble this list, we consulted sources including trade publications, company financial reports, news articles, and internet searches. We also made use of responses to letters from members of Congress to multiple cryptocurrency mining firms seeking information on electricity usage at their facilities. Those letters were issued in August 2022, with most responses from cryptocurrency miners being received in September and October 2022.

We collected details for each facility identified, including the maximum power capacity needed to run the mining rigs in MW. Several cryptocurrency mining facilities identified could be tied to power generating plants listed in our EIA-860, *Annual Electric Generator Report*. Others could not. Of the 137 facilities identified, we have identified maximum electricity use at 101 of those facilities, which we estimate to be 10,275 MW. This amount compares with an average annual power demand of about 450,000 MW in the United States, representing a share of 2.3%.

In practice, cryptocurrency mining facilities frequently run at less than their maximum designed capability. Although cryptocurrency mining units tend to run at a high utilization rate, we lack the data to provide a well-sourced estimate. If we suppose that they operate at 80% utilization, an approximate estimate based on information we have received from a few mining facilities, of the 10,275 MW of capacity that support them, their electricity usage would be about 70 TWh per year, or close to the high end of the range in our top-down estimate.

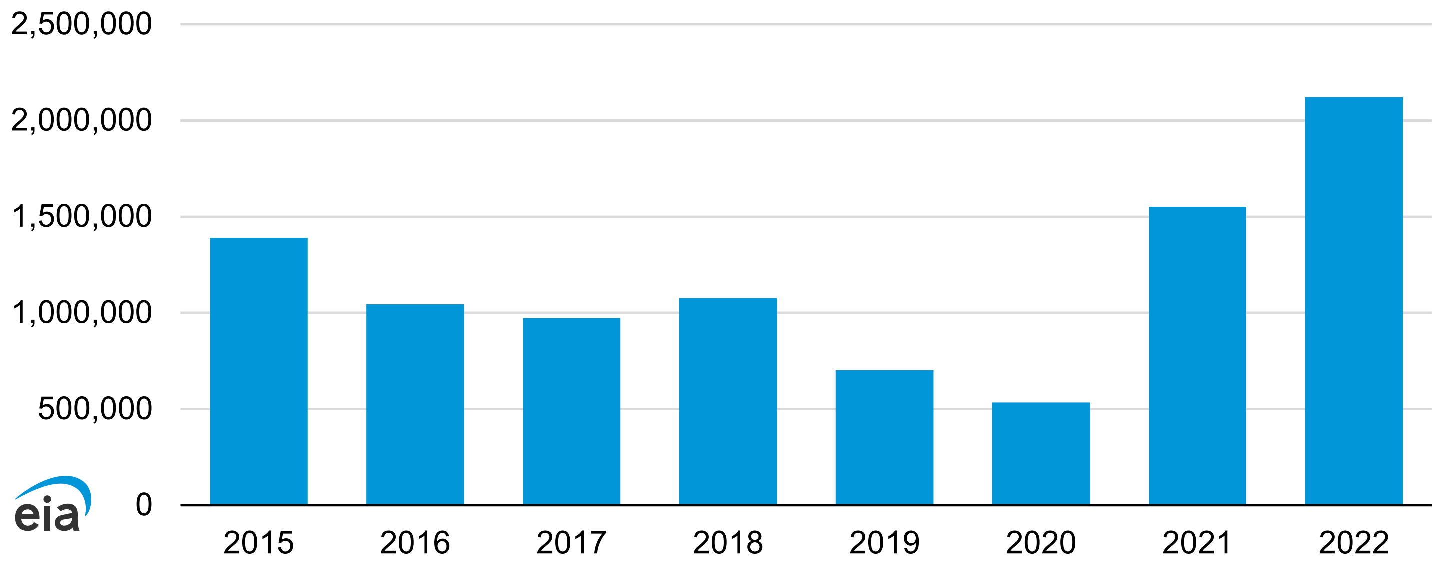
Limited monitoring of electricity use at cryptocurrency mining locations

We have used press articles and company reports to tie some cryptocurrency mining activity to a few facilities via our EIA-923, *Power Plant Operations Report*. Data contained in the EIA-923 survey show generation at nearly every power plant in the United States.

We have been able to track electricity use at a group of five small U.S. power plants in Montana, New York, and Pennsylvania where cryptocurrency mining has occurred. The combined power generation at these five generating facilities rose sharply beginning in 2021 when cryptocurrency miners established operations. Once more, the amount of direct use electricity within the plant itself—used to feed the mining operations—has increased to a larger percentage of the plant's output. Prior to the installation of the cryptocurrency mining equipment, output from the five plants had been much lower. The previous underutilization of these power plants has attracted cryptocurrency miners to these facilities given prospects of dedicated electricity at low rates.

Annual electricity generation at five select power plants with crypto-mining operations (2015–2022)

megawatthour



Data source: U.S. Energy Information Administration
Note: U.S. Energy Information Administration, Form EIA-923, *Power Plant Operations Report*

Next steps

Given the dynamic and rapid growth of cryptocurrency mining activity in the United States, we will be conducting a mandatory survey focused on systematically evaluating the electricity consumption associated with cryptocurrency mining activity, which is required to better inform planning decisions and educate the public. Other government and industry efforts to determine the effects of cryptocurrency mining on the energy system have generally taken the form of studies, which lack the comprehensive, standardized, timely, and consistent nature of a formal data collection. Data gathered during the emergency clearance will provide critical insight that informs our approach moving forward.

In addition, we plan to continue to refine our estimates of electricity consumption associated with cryptocurrency activities in the United States as new information and data become available. In addition to data collected during the emergency clearance, we will continue to track CBECI estimates, refine our list of identified facilities, and review estimates made by third parties.

Principal contributors: Mark Morey, Glenn McGrath, and Hiroaki Minato

[1] EIA, *Electric Power Annual 2022*, Table 2.2, page 10

[2] EIA's clearance package is available here: https://www.reginfo.gov/public/do/PRAViewICR?ref_nbr=202401-1905-002

[3] Sigalos, MacKenzie, CNBC, *Inside China's underground crypto mining operation, where people are risking it all to make bitcoin, December 19, 2021* (https://www.cnbc.com/2021/12/18/chinas-underground-bitcoin-miners-.html)

[4] Letter from Senator Elizabeth Warren, Senator Sheldon Whitehouse, Senator Edward J. Markey, Congressman Jared Huffman, Congresswoman Rashida Tlaib, and Senator Jeffrey A. Merkley to U.S. Environmental Protection Agency Administrator Michael Regan and Secretary of Energy Jennifer Granholm, July 15, 2022, https://www.warren.senate.gov/imo/media/doc/2022.07.15%20Letter%20to%20EPA%20and%20DOE%20Re%20Cryptomining%20Environmental%20Impacts.pdf

[5] Letter from Senator Elizabeth Warren, Senator Sheldon Whitehouse, Senator Edward J. Markey, Senator Jeffrey A. Merkley, Congressman Jared Huffman, Congresswoman Rashida Tlaib, Congresswoman Katie Porter, and Senator Richard J. Durbin to U.S. Environmental Protection Agency Administrator Michael Regan and Secretary of Energy Jennifer Granholm, February 6, 2023, https://www.warren.senate.gov/imo/media/doc/2023.02.06%20Follow-Up%20Letter%20to%20EPA%20and%20DOE%20Re%20Cryptomining%20Environmental%20Impacts2.pdf

[6] https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2023.pdf

[7] https://ccaf.io/cbnsi/cbeci

[8] The White House, Climate and Energy Implications of Crypto Assets in the United States, September 2022, page 5

[9] Cambridge Centre for Alternative Finance: Cambridge Bitcoin Electricity Consumption Index, Methodology

[10] 2022 estimate drawn from International Energy Agency, *Electricity Market Report*, 2023, page 119; updated to 2023 assuming a 2.2 annual growth rate, drawn from *Electricity 2024*, International Energy Agency, p. 8

[11] EIA, International Energy Statistics

[12] https://ccaf.io/cbeci/api/v1.2.0/download/mining_countries

[13] EIA, *Electric Power Monthly*, January 2024 (January-November 2023 data); EIA *Hourly Grid Monitor* (December 2023 data)

[14] EIA estimate of 10,791 kilowatthours per year of electricity consumption per house, EIA, *How much electricity does an American home use?* October 20, 2022

[15] EIA, *Electric Power Monthly*, February 2023, Table 5.4b, page 135