

Code changes could drastically reduce bitcoin's enormous electricity requirements

As the value of bitcoin soars to record levels, the environmental impacts of cryptocurrency mining are attracting scrutiny from governments.

Power-hungry bitcoin miners in the US won a victory of sorts last month when the Energy Information Administration (EIA) agreed to soften its demand for the industry to detail its electricity consumption. But the controversy over bitcoin's surging energy demand and carbon footprint worldwide is unlikely to go away.

The EIA estimated in February that cryptocurrency mining accounts for anywhere from 0.6% to 2.3% of US electricity consumption. Bitcoin is by far the largest of the world's more than 10 000 cryptocurrencies, accounting for around half the total market. To create new bitcoins, mining companies must solve cryptographic puzzles that require vast computational resources. The rapid growth in electricity demand from bitcoin mining has drawn the attention of the Biden administration, some members of Congress, and grid planners concerned about its impact on electricity cost, reliability, and emissions. As *PHYSICS TODAY* went to press, bitcoin was trading at an all-time high price of around \$73 000. Bitcoin mining—and its energy consumption—rises in parallel with the price.

A federal judge in Texas on 1 March issued an order under which the EIA agreed to abort its survey of cryptocurrency miners, destroy information it had gathered, and follow a more deliberate process before reissuing its request. Texas bitcoin miners had objected to the “contrived and self-inflicted urgency” of the EIA's demand, which the agency had made on an emergency basis. An association of bitcoin miners complained in the lawsuit that the information sought was proprietary and could allow competitors to reverse engineer companies' operations. The EIA agreed to follow the regular procedures of the Paperwork Reduction Act,

which includes opportunities for public comment.

Bitcoin capital

With an estimated current mining capacity of 2.7 GW, Texas is the “bitcoin mining capital of the world,” boasts the nonprofit Texas Blockchain Council, which filed suit against the EIA in February. It was joined in the complaint by Riot Platforms, which operates what it says is the largest bitcoin mining plant in North America, with a capacity of 700 MW. A second facility under construction will have a capacity of 1 GW when completed, the company says. For reference, a typical commercial nuclear reactor produces about 1 GW of power.

The bitcoin miners say they reduce their electricity demand and help prevent blackouts by curtailing their operations during peak load periods in exchange for payments from utilities. And when market prices are higher than their revenues from bitcoin mining, the companies can sell back the power that they have purchased under long-term contracts.

Worldwide, bitcoin mining used more energy in 2020–21 than all but 26 countries, according to an October 2023 report by an academic arm of the United Nations. It emitted carbon dioxide equivalent to burning 38 billion kg of coal.

Because of the decentralized nature of bitcoin, no one knows the exact number of mining farms in the world. Estimates of the electricity used in bitcoin mining vary. Both the UN report and the EIA cited figures from the Cambridge Centre for Alternative Finance (CCAF), which in early March estimated current annualized consumption at 163 TWh, or 0.63% of the world's total. Digiconomist, another widely cited index created by Alex de Vries, a PhD candidate at the



Free University of Amsterdam School of Business and Economics, estimated annualized bitcoin consumption at 146 TWh, comparable to the energy consumption of Ukraine. It has put electricity use from the mining of gold, which is often compared with bitcoin as a financial asset, at 132 TWh.

Bitcoin miners say their energy efficiency is steadily increasing and their total energy usage and carbon footprint are puny relative to global electricity consumption and carbon emissions. In a report summarizing operations for the first half of 2023, the Bitcoin Mining Council (BMC), a 57-member association purporting to represent 43% of the global industry, says the entire global mining network (including non-BMC members) would consume 0.21% of global energy production in 2023.

A 400% rise in bitcoin price from 2020 to 2021 was followed by a 140% surge in the worldwide bitcoin mining electricity



RIOT PLATFORMS'S bitcoin mining facility in Rockdale, Texas. With an installed capacity of 700 MW, it is the largest bitcoin mining farm in North America. The company, which produced 6626 bitcoins in 2023, is constructing a larger farm in the state that will have a capacity of 1 GW.

use, according to the UN report. Energy usage then plunged by more than two-thirds from mid 2022 to January 2023 when the price bottomed out at \$15 000 from its previous record high, according to Digiconomist. Electricity usage has climbed steadily upward since then as bitcoin's value has surged.

In bitcoin's energy-intensive validation process, known as proof of work, huge numbers of servers incorporating application-specific integrated circuits (ASICs) compete to add to the blockchain, the currency's publicly distributed ledger. Miners completing a new block are currently rewarded with 6.25 new bitcoins. As the mining network has grown over time, the computing power necessary to create new blocks has increased, since the code automatically adjusts the difficulty to keep the time required for completion of a block steady at around 10 minutes.

Conversely, the difficulty was ad-

justed downward when China's ASICs farms, which had accounted for three-quarters of the world's mining in 2021, largely shut down in response to a late 2021 government ban on cryptocurrency mining. The US is now the world's largest bitcoin mining nation, according to the CCAF, with around 37% of the world's capacity.

The CCAF estimates that when using a typical grid-supplied mix of renewable, nuclear, and fossil-fuel power, bitcoin mining is responsible for 87 million tons of greenhouse gas emissions annually.

The efficiency of ASICs has improved dramatically since they were introduced in 2013. The improvements mainly resulted from miniaturization of the chips, which at a process size around 5 nm currently aren't likely to get any smaller, says Alexander Neumüller, who leads research on the climate impacts of digital assets for the CCAF.

Environmental groups, including Greenpeace and the Environmental Working Group, last year urged bitcoin to change its code to a far lower energy-intensive process called proof of stake. Ethereum, the second-largest cryptocurrency, switched in 2022 to proof of stake, where large holders of the cryptocurrency offer some of their own holdings as collateral to validate new blocks and transactions in exchange for a chance to receive rewards. That change lowered the Ethereum network's energy consumption by 99.9%, to an annualized 7.5 GWh, according to the CCAF.

But large holders of bitcoin have opposed change. The BMC says the energy is required in order to provide network security and tie the cryptocurrency's value to the physical world.

The BMC claims that 60% of the energy consumed by the global bitcoin mining industry is supplied from sustainable, non-

duced an LLM nearly seven times as large. That model, GLaM, outperformed GPT-3 and required one-third the energy to train, according to the ITIF report.

A spokesperson for OpenAI says the company recognizes that training large models can be energy intensive and that it's "constantly working to improve efficiencies." The company gives "considerable thought about the best use of our computing power and support efforts with our partners to meet their sustainability goals," she says.

OpenAI's model-training runs, while individually very energy intensive, often enable customers to skip having to train their own models from scratch, the spokesperson says. "We also believe that large language models can be helpful in accelerating scientific collaboration and discovery of climate solutions."

Microsoft, which introduced its LLM chatbot Copilot (formerly known as Bing Chat) in 2023, is investing in R&D to better measure the energy usage and carbon intensity of AI and find ways to make large models more efficient to train and use, a spokesperson says.

There are practical limits to the size and improvements that can be made to LLMs—and hence limits on their energy consumption. Neil Thompson, director of the FutureTech research project at MIT's Computer Science and Artificial Intelligence Lab, says that halving the errors produced by LLMs requires 1.9 million times the amount of computing.

Jonathan Koomey, who is part of a team of researchers preparing a congressionally mandated report on electricity use in data centers, says that the surge of interest and investment in AI recalls previous IT hype cycles, such as the dot-com craze and the overbuilding of fiber-optic networks in the 1990s. "There are real uses that will come out of AI, but I'm very skeptical that this will be a thing that takes over the whole economy." He says that he isn't sure that AI would improve the accuracy of Google searches. "If you can automate the testing of accuracy, great. But the world is messy and full of bad actors trying to cause trouble, and there are gray areas and ambiguities. You may never be able to solve the accuracy problem."

ITIF's Castro foresees "plenty of places where people will try and fail to use AI or they'll do it because of the novelty where there's no value." Developers, he says, are looking for ways to create smaller models that are just as effective. Caching answers to frequently asked prompts instead of generating entirely new responses for each instance is an example, he says.

David Kramer



AS BITCOIN'S PRICE reaches record levels, the cryptocurrency is expected to attract more power-hungry mining operations.

CO₂-emitting sources—more green energy than is used by almost any other industry sector. The UN report and the CCAF both estimate that about 38% of bitcoin mining's energy in 2021–22 came from clean sources. A July report from Greenpeace identified a similar proportion, while noting that some coal-fired plants that had been slated to close were kept open or even reopened to fill demand from bitcoin mining. The fraction of green power has likely fallen since China's largely hydroelectric-powered miners mostly disappeared, says CCAF's Neumüller.

A 2022 report by the Sierra Club and Earthjustice accused some companies of "greenwashing" by locating their plants in proximity to wind or

solar farms. Unless a company has a power purchase agreement or a direct connection to a renewable supplier, the proportion of renewables they use will be the same as that of the grid from which they draw. Apart from a few publicly traded bitcoin mining companies, few self-report their energy consumption source, Neumüller says.

When bitcoin was launched in 2009, the maximum supply was set at 21 million to keep the currency scarce and prevent inflation. Bitcoins currently number around 19 million. The reward for mining a block is set to periodically halve to reduce the rate at which new bitcoins can be minted. A halving is set for this year.

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