Empirical energy consumption model quantifies Bitcoin's carbon footprint

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Researchers have conducted the first analysis of Bitcoin power

consumption based on empirical data from IPO filings and localization of IP addresses. They found that the cryptocurrency's carbon emissions measure up to those of Kansas City—or a small nation. The study, published June 12 in the journal *Joule*, suggests that cryptocurrencies contribute to global carbon emissions, an issue that must be considered in climate change mitigation efforts.

Bitcoin and other cryptocurrencies rely on blockchain technology, which enables a secure network without relying on a third party. Instead, so-called Bitcoin "miners" guarantee a system without fraud by validating new transactions. Miners solve puzzles for numerical signatures, a process that requires enormous amounts of computational power. In return, miners receive Bitcoin currency.

"This process results in immense energy consumption, which translates into a significant carbon footprint," says Christian Stoll, a researcher at the Center for Energy Markets at the Technical University of Munich, Germany, and the MIT Center for Energy and Environmental Policy Research.

Scientists have growing concerns that Bitcoin mining is fueling an appetite for energy consumption that sometimes draws from questionable fuel sources—such as coal from Mongolia—in addition to hydropower and other low-carbon power resources. And cryptocurrency's energy issues seem to only be getting worse, with the computing power required to solve a Bitcoin puzzle increasing more than four-fold in 2018. While there is a growing push among researchers to quantify Bitcoin's energy consumption in order to better understand its contribution to global climate change, recent studies have struggled to generate accurate estimates.

"We argue that our work goes beyond prior work," says Stoll. "We can provide empirical evidence where current literature is based on

assumptions."

Stoll and his team used IPO filings disclosed in 2018 by all major mining hardware producers to determine which machines miners are actually using and the power efficiencies of these machines. They also used IP addresses to determine emissions scenarios for actual mining locations and compare carbon emissions from power sources used by Bitcoin miners in different locations. Finally, they calculated Bitcoin's carbon footprint based on its total power consumption and estimates from different emissions scenarios. These include a lower limit scenario, in which all miners use the most efficient hardware; an upper limit scenario, in which miners behave rationally by disconnecting their hardware as soon as costs exceed revenue; and a best guess scenario, which accounts for the anticipated energy efficiency of the network and realistic additional energy losses from cooling and IT hardware.

"Our model reflects how the connected computing power and the difficulty of Bitcoin search puzzles interact, and it provides a high precision of power consumption since it incorporates auxiliary losses," says Stoll. "However, the precision of our results strongly depends on the accuracy of the input data, such as the IPO filings for hardware characteristics. The carbon emissions strongly depend on the assumed carbon intensity of power consumption."

Using this model, Stoll and his team estimated Bitcoin's annual energy consumption at 45.8 terawatt hours. This allowed them to calculate an annual carbon emissions range between 22.0 and 22.9 megatons of CO2—equivalent to CO2 emitted by Kansas City and placing Bitcoin's emissions between Jordan and Sri Lanka in emissions rankings (the 82nd and 83rd highest emitters). However, the researchers estimate that the energy consumption estimate would almost double (greatly amplifying emissions estimates) if they were to include all other cryptocurrencies in their consequences.

"We do not question the efficiency gains that blockchain technology could, in certain cases, provide," says Stoll. "However, the current debate is focused on anticipated benefits, and more attention needs to be given to costs."

More information: *Joule*, Stoll et al.: "The Carbon Footprint of Bitcoin" www.cell.com/joule/fulltext/S2542-4351(19)30255-7 , DOI: 10.1016/j.joule.2019.05.012

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