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Could Bitcoin emissions push global warming above 2 °C?

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In a recent commentary, Mora et al.[1] hypothesize that cumulative GHG emissions of Bitcoin alone could amount to ~231.4 GtC within the next 16 yr (on the basis of their median scenario), pushing global warming above 2 °C. To put these numbers in context, the carbon budget of ~231.4 GtC is equivalent to ~63 yr of emissions from global power generation at the rate observed in 2017 (that is, ~3.7 GtC)[2]. Bitcoin mining is undoubtedly electricity intensive. However, the electricity demand scenarios calculated by Mora et al. seem unlikely, as Bitcoin-related emissions would entail a tripling of global electricity generation within the next five years (see Supplement). We regard infrastructure bottlenecks and soaring electricity prices as barriers to such growth levels. For example, global electric power capacity increased by only ~ 17% over the past five years.

The conclusions of Mora et al. on Bitcoin-related GHG emissions are mainly based on estimated electricity consumption for Bitcoin mining in 2017 and the extrapolation of this value to year 2100 at constant energy intensities and emission factors. To estimate Bitcoin electricity consumption in 2017, Mora et al. assume that each Bitcoin block was randomly mined on hardware included in a self-compiled list of 62 devices. As this list contains many old devices with high energy intensities, the resulting average hardware energy intensity and electricity consumption of Bitcoin mining are approximately ten times higher than other estimates (see the Supplementary Information)[3].

More importantly, we believe that the analysis of Mora et al. is flawed because their methodology ignores fundamental constraints imposed by the transaction-processing capacity of the Bitcoin network. The diffusion scenarios presented by Mora et al. for Bitcoin transactions eventually assume ~314.2 billion Bitcoin-related cashless transactions per year. The corresponding throughput of roughly ~10,000 transactions per second would be at least two orders of magnitude higher than Bitcoin's current transaction limits. The maximum transaction rate for Bitcoin is constrained by the effective block size and the block interval, both of which are defined in the Bitcoin protocol[4]. While the effective block size defines the maximum number of transactions per block, the block interval sets the pace at which blocks are added to the blockchain. The current block interval is set to 10 min, whereas effective block size rose from 1 MB to 4 MB megabyte in August 2017 as a result of the Segregated Witness (SegWit) protocol upgrade. Before SegWit, the theoretical maximum throughput had been estimated at 7 to 10 transactions per second, depending on the size of the transaction. After SegWit implementation, the maximum was estimated to be 20 transactions per second[5].

Mora et al. neither mention Bitcoin's transaction limit nor outline how it will be resolved to make their projection plausible. Instead, the applied methodology circumvents the scalability problem by implicitly reparameterizing the Bitcoin protocol to decrease the block interval and increase the number of blocks until the resulting transactions match the number of projected transactions. As the authors sample blocks from their base-year estimates, results are equal to those obtained from scaling electricity consumption in 2017 using projected transactions. Transaction growth is implicitly the sole driver for the electricity growth scenarios presented by Mora et al. However, neither in a reparameterized Bitcoin protocol, nor in the current protocol, is electricity consumption proportional to the transaction rate. Instead, Bitcoin's electricity consumption is exclusively proportional to the hashrate, which is the computational capacity of the Bitcoin network. Hashrate growth, in turn, is driven by complex and mutually dependent relationships between mining rewards, transaction fees, hardware energy efficiency, electricity prices and the Bitcoin market price[6]. Increases in throughput capacity, such as with SegWit, translate to a proportional decrease in electricity consumption per transaction, as the electricity consumption of blocks does not scale with the transaction rate.

In conclusion, we consider the work of Mora et al. to be a timely and interesting starting point for a discussion of the carbon emissions attributable to Bitcoin. However, given the structural limitations of the applied methodology, an enhanced scientific analysis is required to determine Bitcoin-related emissions and their contribution to global warming.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, statements of code and data availability and associated accession codes are available at https://doi.org/10.1038/s41558-019-0534-5.

Data availability

The authors declare that all data supporting the findings of this study are available in the article, the Supplementary Information and in ref. [1].

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Competing interests
The authors declare no competing interests.

Additional information
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