Towards an Adequate Energy Policy Response to the Environmental Threat of Cryptocurrency Mining*

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Introduction Cryptocurrencies, for better or worse, allow their users to conduct payments anonymously or pseudonymously, without access barriers, owing to the absence of centralized oversight by intermediaries [2]. Bitcoin is arguably the most popular cryptocurrency, facing a growing user base [3] and a market capitalization of around $330B at the time of writing. Yet, this archetypal digital asset faces perpetual criticism for its electricity demand [4]. This is unsurprising given the devastating effect its energy requirements have: they were found to lead to carbon emissions of up to 65.4 Mt CO_2 annually [5] – the equivalent of the overall emissions of Greece. While many alternative cryptocurrencies provide similar or better functionality than Bitcoin and consume orders of magnitude less electricity [6], [7], Bitcoin continues to dominate the cryptocurrency market in terms of market capitalization. Regulators have undertaken many attempts to address the energy needs of cryptocurrencies through a plethora of different approaches. Despite these best efforts, regulating cryptocurrencies remains challenging and, ultimately, fruitless [8] as policymakers seem to consistently underestimate the technical complexity involved in efficiently targeting them.

The Role of Consensus Mechanisms in Cryptocurrency Energy Consumption In contrast to the traditional monetary system, in which centralized entities, such as commercial banks, record account balances on behalf of their customers, cryptocurrencies, by design and ideology, reject reliance on distinguished trusted third parties. This makes establishing a canonical view of all balances on a digital currency system consisting of distrusting parties an engineering challenge. Bitcoin has first solved this challenge through a cryptography-based incentive system called Proof-of-Work (PoW): Bitcoin's PoW protocol probabilistically releases rewards and redistributed fees to those network participants who provide the solution to a complex cryptographic puzzle. The difficulty of this puzzle is not pre-defined but adapts depending on the computational power provided by the network. Under the assumption that a rational network participant would use their expected rewards to offset their costs for solving the cryptographic puzzle, it stands to reason that the costs participants are willing to incur are in economic equilibrium with the rewards. And indeed, a high positive correlation between Bitcoin electricity consumption and the Bitcoin price has been observed [9]. Shocks to the block reward, such as drops in the price of Bitcoin or a "halving event", and changes on the cost side (e.g., growing electricity prices at the end of the wet season in China) suggest that this assumption is reasonable [10], [11].

Alternative Consensus Mechanisms In recognizing this issue, a plethora of alternative consensus mechanisms have been proposed [12]. Amongst the most popular ones is Proof-of-Stake (PoS). While there are ongoing debates about whether PoS or PoW are more decentralized or secure, from an end-user perspective, the protocols arguably provide similar functionalities. Yet, PoS is clearly preferable from a sustainability perspective, since no costly cryptographic puzzle-solving is needed. Instead, the likelihood of a participant being selected is proportional to cryptocurrency holdings locked. Thus, the electricity consumption of PoS was found to be three orders of magnitude lower than that of PoW [1], [4], [13]. Recently, Ethereum, the cryptocurrency with the second-largest market capitalization, successfully migrated from PoW to PoS after several years of preparation. However, PoW remains hardly contested in Bitcoin circles.

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Potential Policy Measures Regulators have begun to target cryptocurrency activity, predominantly to prevent criminal activity and capital outflows, but also to address sustainability. Measures of the past have predominantly focused on fiscal interventions [14] and prohibitive regulations [15], addressing the operators of cryptocurrency networks. An overview of potential policy measures by Gola and Sedlmeir [8] also identifies measures ranging from fiscal interventions, e.g., in the form of tax credits and other monetary benefits, to bans. However, unfortunately, a global carbon emissions tax that would be needed to address the transnational nature of decentralized cryptocurrencies seems out of reach for the time being. Less popular proposals included design-side policies, such as pushing for voluntary re-designs of highly electricity-consumptive protocols [15]. Consumer-focused policies were rarely introduced, and where they were, often made unrealistic assumptions, such as sovereign control over internet traffic [16].

Failures of Regulation There are many examples of unsuccessful regulations targeting cryptocurrency operations. A case study that can be used to illustrate regulatory challenges globally is China. The Chinese government has undertaken multiple initiatives to stop cryptocurrency activities, starting with severely restricting the use of cryptocurrencies in 2017. These activities culminated in a ban on cryptocurrency network operations in 2021, enforced with reference to environmental concerns (whether this was indeed the key motivation has been subject to controversies). However, while this ban had a temporary effect on domestic cryptocurrency activity, it led to a mere relocation of operators to other regions, predominantly the U.S. and Kazakhstan. Hence, despite this regulatory intervention, cryptocurrency electricity consumption, and with it, the corresponding CO_2 emissions, remained at record levels throughout 2021. Bans can also be considered ineffective and inefficient from an economic perspective compared to, for instance, taxing carbon emissions. This indicates that it may not be the best approach for regulators to engage in outright bans of cryptocurrencies to effect global improvements in their sustainability. Yet, it should be noted that bans on cryptocurrency use could have the effect of decreasing cryptocurrency prices, which would lead to a decrease in electricity consumption in mining in the economic equilibrium model sketched above. On the other hand, such measures may be difficult to justify when they discriminate between cryptocurrencies with more or less energy-efficient consensus mechanisms, and may also severely threaten innovation in this domain.

Cryptocurrency Users In countries of the Global North, cryptocurrencies are primarily pursued as speculative forms of investment [17], [18]. Countries of the Global South, on the other hand, yield a different user profile: Nigeria, Africa's "Crypto Capital", for example, experiences economic stress due to an ongoing recession coupled with rising inflation. This underlying condition, combined with an outdated banking sector [19], led many Nigerians to regularly and routinely employ cryptocurrencies as a means of payment [20] despite a rejective stance of the government [21].

User Expertise and User Concerns An under-researched topic that contributes to cryptocurrency regulation effectiveness is user expertise: particularly the question of whether users of cryptocurrencies understand the potentially dramatic environmental effects of these instruments. The results of recent fieldwork in Nigeria [1] show that, on average, Bitcoin users *underestimate* its electricity consumption. They also demonstrate a positive correlation between participants' ability to estimate Bitcoin's electricity consumption correctly and their support of measures to counteract Bitcoin's CO_2 footprint. The data furthermore suggest that even those users that consider themselves experts often lack a basic understanding of the mechanisms behind Bitcoin. The results align with consumer knowledge assessments in the wider financial products space that indicate that consumers often have little knowledge of the key properties of the products they use [22], [23].

Consumer Education To develop effective strategies to reduce the popularity of PoW cryptocurrencies, and thereby, ultimately, their electricity demand, decision-makers must realize that such strategies cannot be targeted at operators. More effective strategies, instead, must focus on the end users of cryptocurrencies and empower them to make more sustainable choices. Energy labelling, i.e. providing key sustainability metrics to cryptocurrency users at the point of exchange, is one potentially suitable measure to achieve customer education. Ultimately, regulators need to work creatively and embrace the principle of *thinking global and acting local* to address cryptocurrencies that transcend national borders.

References

[1] M. Platt, S. Ojeka, A.-E. Drăgnoiu, O. E. Ibelegbu, F. Pierangeli, and J. Sedlmeir, *How to make users adopt more sustainable cryptocurrencies: Evidence from Nigeria*, Jul. 2022. [Online]. Available: `https://arxiv.org/pdf/2208.00280.pdf`.

[2] G. P. Kumar, "Cryptocurrency – the next big thing," *Recent trends in management and commerce*, vol. 3, no. 1, pp. 14–19, Mar. 2022.

[3] S. Park, S. Im, Y. Seol, and J. Paek, "Nodes in the Bitcoin network: Comparative measurement study and survey," *IEEE Access*, vol. 7, pp. 57 009–57 022, Apr. 2019.

[4] A. Rieger, T. Roth, J. Sedlmeir, and G. Fridgen, "We need a broader debate on the sustainability of blockchain," *Joule*, vol. 6, no. 6, pp. 1137–1141, Jun. 2022.

[5] A. de Vries, U. Gallersdörfer, L. Klaaßen, and C. Stoll, "Revisiting Bitcoin's carbon footprint," *Joule*, vol. 6, no. 3, pp. 498–502, Mar. 2022.

[6] M. Platt, J. Sedlmeir, D. Platt, *et al.*, "The energy footprint of blockchain consensus mechanisms beyond proof-of-work," in *Companion Proceedings of the 21st International Conference on Software Quality, Reliability and Security*, IEEE, 2021, pp. 1135–1144.

[7] J. Sedlmeir, H. U. Buhl, G. Fridgen, and R. Keller, "The energy consumption of blockchain technology: Beyond myth," *Business & Information Systems Engineering*, vol. 62, no. 6, pp. 599–608, Jun. 2020.

[8] C. Gola and J. Sedlmeir, "Addressing the sustainability of distributed ledger technology," Bank of Italy, Occasional Paper 670, Feb. 2022. [Online]. Available: `https://www.bancaditalia.it/pubblicazioni/qef/2022-0670/QEF_670_22.pdf` (visited on 01/09/2022).

[9] M. Maiti, "Dynamics of bitcoin prices and energy consumption," *Chaos, Solitons & Fractals: X*, vol. 9, p. 100 086, Dec. 2022.

[10] J. Sedlmeir, H. U. Buhl, G. Fridgen, and R. Keller, "Recent developments in blockchain technology and their impact on energy consumption," *Informatik Spektrum*, vol. 43, pp. 391–404, Nov. 2020.

[11] J. Stinner, "On the economics of Bitcoin mining: A theoretical framework and simulation evidence," in *Proceedings of the 43rd International Conference on Information Systems*, 2022-12. [Online]. Available: `https://aisel.aisnet.org/icis2022/blockchain/blockchain/7/`.

[12] M. Platt and P. McBurney, "Sybil in the haystack: A comprehensive review of blockchain consensus mechanisms in search of strong Sybil attack resistance," *Algorithms*, vol. 16, no. 1, p. 34, Jan. 6, 2023.

[13] U. Gallersdörfer, L. Klaaßen, and C. Stoll, *Energy efficiency and carbon footprint of proof of stake blockchain protocols*, Jan. 2022. [Online]. Available: `https://www.carbon-ratings.com/dl/pos-report-2022` (visited on 01/09/2023).

[14] V. Oğhan, "Environmental policies for green cryptocurrency mining," in *Handbook of research on challenges in public economics in the era of globalization*, Ş. Akkaya and B. Ergüder, Eds., IGI Global, Mar. 2022, ch. 13, pp. 217–227.

[15] J. Truby, R. D. Brown, A. Dahdal, and I. Ibrahim, "Blockchain, climate damage, and death: Policy interventions to reduce the carbon emissions, mortality, and net-zero implications of non-fungible tokens and Bitcoin," *Energy Research & Social Science*, vol. 88, p. 102 499, Jun. 2022.

[16] S. K. Fakunmoju, O. Banmore, A. Gbadamosi, and O. I. Okunbanjo, "Effect of cryptocurrency trading and monetary corrupt practices on Nigerian economic performance," *Binus Business Review*, vol. 13, no. 1, pp. 31–40, Jan. 2022.

[17] C. Baek and M. Elbeck, "Bitcoins as an investment or speculative vehicle? a first look," *Applied Economics Letters*, vol. 22, no. 1, pp. 30–34, Aug. 2014.

[18] R. Auer and D. Tercero-Lucas, "Distrust or speculation? the socioeconomic drivers of US cryptocurrency investments," Bank for International Settlements, Basel, Switzerland, Working Paper 951, Jul. 2021. [Online]. Available: `https://www.bis.org/publ/work951.pdf` (visited on 01/09/2023).

[19] E. S. Osuagwu, W. A. Isola, and I. C. Nwaogwugwu, "Measuring technical efficiency and productivity change in the Nigerian banking sector: A comparison of non-parametric and parametric techniques," *African Development Review*, vol. 30, no. 4, pp. 490–501, Dec. 2018.

[20] T. Lawal, *How Nigerians are increasingly turning to BTC and other altcoins*, Mar. 2021. [Online]. Available: `https://cryptotvplus.com/2021/03/how-nigerians-are-increasingly-turning-to-btc-and-other-altcoins/` (visited on 01/09/2023).

[21] A. Bakare, "Cryptocurrency prohibition in Nigerians' best interest — Emefiele," *CBN Update*, vol. 3, no. 2, pp. 16–17, Feb. 2021.

[22] M. Ramchander, "Measuring consumer knowledge of life insurance products in South Africa," *South African Journal of Business Management*, vol. 47, no. 2, pp. 67–74, Jun. 2016.

[23] S. Sukumaran, T. S. Bee, and S. Wasiuzzaman, "Cryptocurrency as an investment: The Malaysian context," *Risks*, vol. 10, no. 4, p. 86, Apr. 2022.