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SUSTAINABILITY OF ENERGY SOURCES AND ENERGY EFFICIENCY: A STUDY ON THE EFFECTS OF SDG 07 ON THE ENVIRONMENTAL IMPACTS OF CRYPTOASSET MINING

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ABSTRACT
This study investigates the relationship between crypto mining, the sustainability of energy sources, and energy efficiency, focusing on environmental, economic, and social impacts in the context of SDG 07 (affordable and clean energy). Crypto mining still largely relies on non-renewable sources such as coal, generating significant greenhouse gas emissions and putting climate goals at risk. This paper proposes a preliminary analysis of this energy modality with respect to environmental impacts and investigates the role of emerging technologies, energy efficiency and public policies to promote sustainable practices in this area. To this end, an exploratory and bibliographic-documentary research was developed and methodologically developed within the approach of climate litigation and regulation of crypto asset mining, with emphasis on the integration of renewable sources. The study provided subsidies for the formulation of public policies that integrate mining into the sustainable energy transition.

Keywords: Crypto Mining. Energy Efficiency. Energy Sustainability.

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INTRODUCTION

According to CVM (2025), cryptoassets are "virtual assets", protected by cryptography, present exclusively in digital records, whose operations are executed and stored in a computer network, being the pioneer cryptoasset, and also the best known, Bitcoin, which is a type of currency that is based on blockchain technology. Within this scenario, cryptoassets started to be used for other purposes, such as the initial offering of virtual assets (Initial Coin Offering), according to CVM (2025), offering, in exchange for raising financial resources for investments, such as virtual assets (cryptocurrencies or tokens linked to participation in the results of ventures or even pre-fixed remunerationon investment capital, for example).(CVM, 2025).

In this context, the terminology "mining" alludes to the exploration of precious metals, referring to the sense of preciousness that this technological innovation could add to the market as a whole (SANTOS, PANDOLFO and ANDREOLA, 2019). However, the use of mining cryptoassets as a source of investment will not be addressed in this research, as the focus of this study is guided by the discussion of renewable energy consumption or not, which is embedded in cryptocurrency mining, prioritizing renewable energy sources. In addition, the mining of cryptoassets emerges as a relevant activity, given that, to a large extent, it still depends on non-renewable energy sources, contributing to the increase in carbon emissions.

These discussions are consistent with the Sustainable Development Goals (SDGs) of the 2030 Agenda, especially with emphasis on SDG No. 07, which aims to ensure "clean and affordable energy", as well as the discussion held, in particular, during the 28th United Nations Conference on Climate Change (COP28), resulting in the firm determination for the "energy transition", highlighting the need for a new energy model, with the aim of tripling the capacity of renewable sources by 2030 and doubling global energy efficiency in the same period (UN BR, 2025).

It is worth mentioning that the dynamics of the sustainable impacts inherent to the mining of cryptoassets involve economic and regulatory variables that go beyond the scope of this study. And even though crypto mining involves several other assets in this segment,

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our study will be based on mining carried out on the Bitcoin network that is based on blockchain technology[4].

OBJECTIVE

Investigate the relationship between crypto asset mining, the sustainability of energy sources, and energy efficiency in the context of SDG 7 ("Affordable and Clean Energy"), highlighting not only core environmental impacts such as emissions and energy consumption, but also emerging business models that utilize Bitcoin's blockchain infrastructure and its mining to influence energy efficiency and sustainability.

METHODOLOGY

This study adopted the methodological approach of documentary and bibliographic research, with an exploratory character, involving a combination of qualitative and quantitative analyses based on studies already carried out. Data collection was carried out from websites and referential scientific and academic sources, such as Google Scholar, Capes, Scielo, among others, focusing on works that address topics such as energy sustainability, energy efficiency, renewable energies, climate justice, SDG n. 07, and crypto asset mining.

In addition, standards and legislation that address the intersection between crypto mining and environmental issues were investigated, with an emphasis on climate justice.

The data collection procedures also involved the systematization of information on the impacts of crypto asset mining, energy efficiency, and the sustainability of energy sources, always considering the central thematic axes of SDG No. 07 of the 2030 Agenda.

Data analysis was carried out through a qualitative approach, with the use of content analysis techniques to extract significant information from the selected sources. Content analysis uses analysis techniques that aim to infer knowledge through quantitative or non-quantitative indicators (BARDIN, 1977).

The research also considered an analysis of laws and public policies related to climate justice and their applicability to crypto mining.

[4] CVM (2025): "Transactions published on the network are grouped and recorded in blocks, so that each block accepted on the network connects to the one immediately preceding it, and so on, forming a sequence or chain of blocks (blockchain)".

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In addition, literature searches were conducted on quantitative data to identify trends in data related to energy consumption and the environmental impacts of crypto asset mining.

DEVELOPMENT

Bitcoin, a digital currency proposed by Satoshi Nakamoto in a 2008 paper, emerged at the time in response to criticism about the value of paper money. The proposal aimed to create a system of electronic transactions without the need to rely on a third party, such as financial institutions, promoting a decentralization of the financial system and reducing intermediation in transactions (NAKAMOTO, 2008).

It was found, at first, that the growing demand for cryptoassets, since their creation in 2008, has resulted in pressure on global energy resources, challenging established climate commitments (Vries, 2022).

This is because, as Vries (2022), a researcher at the School of Business and Economics at the Vrije Universiteit Amsterdam, points out, the growing focus on climate risks and carbon emissions has intensified debates about the energy sources used in cryptocurrency mining, especially considering their significant environmental impact. This debate gains relevance as energy costs and implications for the sustainability of the sector become more evident."

The analysis of the environmental consequences of bitcoin mining often has inconsistencies, largely due to the use of two widely used models to estimate its energy consumption: the Cambridge Bitcoin Electricity Consumption Index (CBECI) and the Digiconomist Index. However, these models face important limitations, as they are based on generalized and unverified assumptions, such as uniformity in electricity costs and Productive Energy Use (PUE) values. In addition, both indices deal with difficulties with the often incomplete or outdated data, which compromises the accuracy of estimates on Bitcoin's energy consumption. These observations underline the need for more robust and empirical data-based methods to calculate the energy footprint of the grid (DASAKLIS et al., 2025).

Generally speaking, Bitcoin's energy consumption (BEC) has significant implications for green regional economies, especially in the United States, Europe, and Asia. A study by Gunay, Kirimhan, and Demiralay (2025) highlights that the interaction between emerging financial technologies, such as Bitcoin, and global environmental goals must be carefully

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checked. The authors emphasize the importance of coordinated actions to address crypto-related energy consumption and global sustainability goals.

According to the definition presented by Seibt (2024), cryptocurrency mining is the process of validating and including new transactions in the blockchain, being responsible for increasing the circulation of cryptocurrencies, just as the central bank does with traditional money. The difference is that, in the case of digital currencies, there is no central authority, but algorithms that govern the process. Mining, moreover, is a highly competitive activity that consumes a large amount of electrical energy due to the processing power required to solve the mathematical problems.

Also according to the same author, cryptocurrency miners are individuals, computers or computer networks responsible for performing complex calculations to validate transactions and generate new units of cryptocurrencies. Additionally, they play a crucial role in maintaining the security of the network, as the mining process helps protect against fraud and attacks.

The adoption of technologies such as blockchain has expanded across diverse industries and supply chains, and is valued for its ability to offer transparency between all parties involved. However, while it brings potential benefits, the use of blockchain presents several challenges, including issues of efficiency, technical complexity, environmental impacts, and the need for a proper regulatory framework (BABAEI et al., 2025).

A study by Hajiaghapour-Moghimi et al. (2022) discusses an energy efficiency program that aims to incentivize miners to utilize high-efficiency cryptocurrency mining devices (CMDs). The approach suggests that, if implemented, a standard that prohibits the use of inefficient CMDs and adopts a deliberation-reward strategy could improve miners' profitability.

Furthermore; according to Vranken (2017), ASICs (Application-Specific Integrated Circuits) initially developed for Bitcoin mining began to be adapted to other mining protocols, which boosted the area, making it attractive for the development of integrated circuits with the aim of improving speed, reducing power consumption, and reducing the size of devices.

Even in a context of polishing the emerging sector in search of energy savings, it was observed that in 2021 there was a ban on cryptocurrency mining in China, reflecting the growing concern about the environmental impacts associated with these activities, especially in relation to the consumption of energy from fossil sources (Cambridge Center for Alternative Finance, 2023).

This move by the Chinese government has caused a rapid migration from the country where the cryptocurrency is mined. An example was Kazakhstan, one of the main destinations for Chinese miners after the ban in their home country. In the study by Gonçalves (2022), the migration of miners to Kazakhstan in search of cheaper energy is mentioned, which caused a substantial increase in the demand for electricity, leading to energy shortages and overloading the country's electrical infrastructure.

RUDD et al. (2023) highlight that there is an urgent need for research related to financial inclusion, resilience in vulnerable regions, and macroeconomic and geopolitical interaction in the face of Bitcoin adoption. They further emphasized that the evolution of the Bitcoin ecosystem requires clear and credible research to guide public policy and decisions on its impact related to financial inclusion and resilience in economically and politically unstable areas at the global level.

Other studies, such as the one by Menati et al. (2023), state that cryptocurrency mining has a specific impact on power grids, affecting three main aspects: the carbon footprint, grid reliability, and electricity prices. The authors point out that the variation in the carbon footprint according to the location of the mining can be significant, and can reach up to 50% difference in relation to the average of the system. The research also suggests that by adjusting the flexibility of mining loads, it is possible to reduce energy shortages and market disruptions. The study proposes that public policies should facilitate the participation of large mining facilities in wholesale markets.

Returning to the issue of China's decision to prohibit the mining of crypto assets in its territory, according to JIANG (2021) the fact is still very much based on its participation in the Paris Agreement, which aims to limit the increase in the global average temperature, committing to reduce 60% of carbon emissions by 2030. However, it is estimated that the carbon emission pattern of digital asset miners, in general, will become a potential barrier to the detriment of China's emissions reduction targets.

This point is crucial, given that cryptocurrency mining, within the specific scope of the energy transition (fair and equitable), especially considering developing countries, brings significant environmental impacts.

It should be noted that, according to the University of Cambridge, "Bitcoin mining consumes more electricity annually than all of Argentina" (Cambridge Center for Alternative

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Finance, 2023), putting significant pressure on global energy systems and sustainability commitments.

Succinctly, the paper by Rasool Malik, Aslam, and Ferreira (2024) investigates the relationship between Bitcoin's electricity consumption and the prices of conventional and renewable energy markets, using a multifractal analysis. The results show a persistent correlation between Bitcoin's energy consumption and energy prices, being strongest in the fossil fuel market, especially coal. The study suggests that dynamic changes in Bitcoin's energy consumption should be considered in portfolio management for risk management strategies, in the case of the consumption of these energies.

Still on the energy consumption metrics from crypto asset mining, there are studies such as the one conducted by McCook, in which, based on a set of processors selected from news and research, he estimated that approximately 80% of the machines used in Bitcoin mining belonged to chip manufacturing companies, while the other 20% were processors available in the retail market. (MCCOOK, 2015).

Another more recent study, Küfeoğlu's, conducted in 2019, investigated computational use in Bitcoin mining, using 160 GB (1 GB, gigabyte, = 1 billion bytes 1,000,000,000 bytes) of data from the Bitcoin blockchain and 269 distinct hardware models to analyze efficiency over different periods and more accurately estimate energy consumption. The study highlighted the relevance of the advancement of technologies for the energy consumption of Bitcoin mining, indicating that, if mining continued to use CPUs, consumption would reach 11,000 TWh, (1 TWh, terawatt-hour, = 1 trillion watts consumed per one hour) a value that would represent almost half of global energy consumption (Küfeoğlu, 2019).

Within the perspective of positive environmental impacts, on the other hand, proponents of crypto mining claim that it can be a positive force for economic growth, technological innovation, the conservation of natural resources (if coupled with renewable sources), and the promotion of social justice, especially in terms of financial inclusion and economic decentralization.

Regarding the positive economic impacts, especially with regard to financial inclusion and job creation, studies such as those by Tapscott and Tapscott (2016) narrate that blockchain has the potential to transform the way financial transactions are carried out, increasing transparency and security, characteristics that are essential for the promotion of financial inclusion, Thus, the decentralization of currency and the elimination of

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intermediaries can reduce economic inequality and promote equity in access to financial services, especially in emerging economies.

As a result, crypto mining and blockchain technology have the power to not only generate economic growth but also democratize access to the financial system, especially in areas where the lack of traditional banking services is an obstacle to economic development (Tapscott & Tapscott, 2016).

In a survey conducted by Seibt (2024), one of his respondents states that Bitcoin can be an ideal solution for small countries marginalized on the global economic stage, such as El Salvador. Although the media portrays the Salvadoran economy as unstable, the interviewee points out that Bitcoin mining carried out in the country's volcanoes represents a form of wealth building that is not properly recognized by the media.

In this sense, the study entitled "Bitcoin: the feasibility of mining in Brazil" considering aspects such as energy consumption, operating costs and economic impacts observed that the average energy consumed in the production of a Bitcoin in Brazil oscillates between R$57,028 and R$66,295 thousand reais, indicating that mining activity may be more viable in regions with lower energy costs. Although the study focuses on the Brazilian context, it suggests that Bitcoin mining can have a positive impact on local economies, especially in areas with abundant and low-cost electricity, where the activity can become a significant source of revenue (SANTOS; OLIVE TREE; RIBEIRO, 2022).

Another study in the same vein is that of VOLOSHYN et al. (2023), which shows that energy efficiency problems in bitcoin mining have become a challenge to the possibilities of blockchain technology, requiring new engineering and management policies. A comparative analysis of energy consumption in bitcoin generation and global consumption revealed the lack of reliable methods for evaluating the energy of these technologies. The solution involves large mining companies located in areas with cheap energy and their own resources, as well as energy alternatives.

In any case, cryptocurrencies depend on large volumes of energy, especially non-renewable energy, to be generated through mining, generate a significant environmental impact, and this impact can affect the fulfillment of the 2030 Agenda, especially SDG n.07, that is, the promotion of clean energy sources (Divino et Antunes, 2021).

That said, in recent years, academic studies on energy consumption on the Bitcoin network have stood out, which reveal a change in the perception of its environmental impact. Initially, many focused on the negative effects of mining, but more recently, the

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literature has highlighted innovations in the adoption of renewable energy sources and in the optimization of energy use. In addition, bitcoin mining has been seen as a solution for harnessing surplus energy, with applications such as the use of trapped gas in the oil and gas industry, which can reduce methane emissions rather than releasing it directly into the atmosphere (DASAKLIS et al., 2025; DE VRIES, 2018; KAKINUMA, 2023; PROELSS et al., 2023; RUDD et al., 2024; TRUBY, 2018).

Consequently, bitcoin mining transforms physical energy into cryptographic energy, through computational work to secure the network. This process leads to the creation of new digital business models, which monetize previously wasted energy resources, generating value from previously inefficient sources. By utilizing diverse and decentralized energy sources, bitcoin mining creates a global infrastructure that underpins the network and fosters innovative opportunities in the digital economy. The Bitcoin blockchain has the potential to foster new economic paradigms by harnessing resources in innovative ways, with circular and symbiotic models being relevant in this context (DASAKLIS et al., 2025; GEISSDOERFER et al., 2020)

Still in the direction of the possible benefits of crypto asset mining, Revoredo (2021) brings an interesting example of the sustainable use of Bitcoin mining that takes place on a tulip farm in the Netherlands, where renewable electricity is used to power the mining operation. This practice allows the farm to operate in a "carbon free" manner, with near-zero gas emissions, demonstrating how the combination of bitcoin mining and renewable energy can significantly reduce environmental impact.

Another study carried out, this time by David et al. (2025) on the use of blockchain technology in renewable energy projects in sub-Saharan Africa highlighted the importance of social dynamics in both the initiation and execution of these projects, as well as the essential role of blockchain in promoting energy security. The authors emphasize that in order to achieve the goals of decentralization, decarbonization, and digitalization of renewable energy, it is necessary to update the theory of sociotechnical systems (STS). The interdependence between critical success factors (CSF) and blockchain's technological contribution is crucial to the success of renewable energy projects. Lack of adherence to this interdependence can result in low accessibility and difficulties in scaling technological innovations, compromising the success and adoption of energy systems.

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Returning to Revoredo (2019), bitcoin mining can be a viable solution to deal with the surplus of renewable energy. The practice makes excess energy generated by sources such as solar and wind profitable, also functioning as an indirect form of energy storage.

In the author's view, bitcoin miners have three characteristics that make them special customers for renewable energy companies: 1) electricity accounts for the majority of their operating costs, 2) their ability to consume energy intermittently, and 3) their flexibility in the location of mining machines, which can be positioned close to electricity generation sources to reduce transmission losses.

As noted by the author, personalities such as Jack Dorsey, former CEO of the former Twitter and current CEO of Square, made a controversial statement by stating that the Bitcoin network encourages renewable energy. This aligns with the idea that bitcoin miners can help promote the use of renewable energy due to their flexibility and ability to consume electricity efficiently, especially when the supply of renewable energy is abundant.

FINAL CONSIDERATIONS

This study sought to investigate the relationship between crypto mining, energy consumption, and environmental impacts, highlighting the dependence on non-renewable sources, such as coal, and their contributions to carbon emissions.

In addition, he reflected on the sustainability of the energy sources used in this process and energy efficiency in the context of SDG 7, which seeks to ensure universal access to clean and affordable energy.

The analysis suggested that in order for crypto mining to align with the energy efficiency goal of sustainability goals, it is imperative to develop and implement even more efficient technologies, as well as public policies that encourage the transition to renewable energy sources, which would be the most suitable for this sector.

The research also identified emerging business models that utilize Bitcoin's blockchain infrastructure, which can play a crucial role in improving the energy efficiency and sustainability of the sector, aligning with the SDG 7 goals.

In addition, crypto mining suggests that it can be an important tool for financial inclusion and economic development, as long as the management of its environmental impacts is adequately addressed.

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Therefore, for crypto mining to become truly sustainable, a continuous effort is needed to transition to renewable energy sources, adopt technologies with low environmental impact, and implement effective regulations.

These points are essential to ensure that the crypto-asset mining sector contributes positively to meeting the goals of the 2030 Agenda, especially SDG 7, especially in the spirit of a fair and equitable energy transition, which promotes climate justice.

It is therefore recommended to continue investigations into regulation and new technologies that favor the transition to more sustainable mining practices, in line with the SDGs.

Finally, there is a feeling that this study can serve for a deeper understanding of crypto mining, highlighting the urgent need for a balance between innovation and sustainability.

Finally, given the growing demand for crypto assets and their environmental impacts, the sustainability of energy sources becomes a crucial factor for the long-term viability of this activity. And energy efficiency in the mining of cryptoassets emerges, therefore, as a logical premise to mitigate the negative effects of high energy consumption, especially in a scenario where increasing the supply of renewable sources is essential if the objective is to meet SDG n. 07 with regard to its principles of sustainable development. Thus, based on this positive relationship between the renewable energy surplus and the increase in demand for cryptoassets, it is suggested to assimilate these ideas from a concept that has already been discussed by several researchers and organizations, namely, Digital Sustainability.

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