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Environmentally friendly crypto-assets in the context of sustainable development in the digital economy

Abstract

Purpose: The aim of this study is to analyse crypto-assets with a limited environmental impact and to assess the impact of the Proof of Work mechanism on the natural environment.

Methodology: The study is of a review and analytical nature and is based on an analysis of academic literature, reports and regulatory documents from 2010 to 2025. The analysis examined the impact of PoW on energy consumption, carbon footprint, electronic waste and socio-economic aspects, and compared it with the Proof of Stake and Pure Proof of Stake mechanisms.

Results: The analysis showed that PoW is characterised by high energy consumption and a significant environmental impact. Alternative consensus mechanisms are characterised by lower energy consumption and may reduce the negative environmental impact of blockchain technology.

Conclusions: Crypto-assets with a limited environmental impact may represent a direction for the development of more energy-efficient blockchain solutions; however, they require further research and greater transparency regarding environmental data.

Keywords: green crypto assets, sustainable development, blockchain, financial market, ESG

JEL Codes: G20, Q56, Q33, G18

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Introduction

The dynamic development of blockchain technology and crypto-assets in recent years has significantly influenced the shape of the modern digital economy, while revealing a number of significant challenges – especially in the environmental area. At the heart of the debate is the high energy intensity of consensus mechanisms, especially Proof of Work, which translates into increasing energy consumption and greenhouse gas emissions. However, this issue goes beyond the ecological aspect itself, also encompassing social, economic and regulatory issues, which points to the need to look for more sustainable models of blockchain technology. In response to these challenges, so-called green crypto-assets are being developed, which use less energy-intensive consensus mechanisms, such as Proof of Stake or its variants, as well as support initiatives related to renewable energy sources. They are increasingly linking technological innovation to the SDGs, offering new financing opportunities for low-carbon projects and increasing the transparency of the energy market.

Limiting energy consumption in cryptocurrency systems should be sought in the way consensus mechanisms work. In the case of both bitcoin and ethereum, the basis of operation is a distributed blockchain database, in which successive packages of transactions (blocks) are attached to the existing chain by network participants. This process takes place without central supervision, and its participants are paid for their participation. An important difference appears in the way the entity responsible for adding a new block is selected. In the Proof of Work system, computing power plays a decisive role, participants compete by performing a huge number of operations, which translates into very high energy consumption. In contrast, in the Proof of Stake model, the capital you own in the form of cryptocurrency deposited on the network is crucial. In this case, the selection of the participant is based on their participation and not on their computing capacity, which significantly reduces the energy requirement.

The aim of this study is to identify and analyze green crypto-assets as a tool to support sustainable development in the digital economy, with particular emphasis on the impact of the Proof of Work consensus mechanism on the natural environment. Particular attention was paid to the environmental consequences of blockchain technology, including electricity consumption, CO₂ emissions, and the generation of electronic waste. The study also incorporates alternative consensus mechanisms, such as Proof of Stake, analysing the potential in reducing the negative environmental impact of cryptocurrencies. An important element of the analysis is also the assessment of the importance of green crypto-assets in the context of financial market transformation in accordance with the principles of sustainable development.

1. Theoretical foundations of pro-environmental crypto-assets

Presenting the theoretical foundations of pro-environmental cryptoassets is an essential point due to the definition of a precise scope of research. Pro-environmental crypto-assets can be defined as those that maintain the integrity of the blockchain

while being energy-efficient and reducing carbon emissions (Koemtzopoulos, Zournatzidou, Sariannidis 2025). They can be referred to as digital financial assets based on distributed ledger technology (DLT), the design and operation of which are aimed at reducing the negative impact on the environment, in particular by reducing electricity consumption, carbon dioxide emissions and the amount of electronic waste compared to traditional cryptocurrencies using the Proof of Work consensus mechanism. (Stoll, Klaaßen, Gallersdörfer 2019). Pro-environmental crypto-assets are defined as digital assets that use energy-efficient consensus mechanisms and solutions that reduce the negative impact of blockchain technology on the environment, in particular by reducing energy consumption and CO₂ emissions (Ali et al. 2024). The goal of pro-environmental crypto assets is to reduce the carbon footprint in the process of cryptocurrency mining and validation. Green blockchain means using blockchain technology in an environmentally sustainable way, prioritizing the reduction of carbon emissions and energy consumption (Alzoubi, Mishra 2023). A key component of pro-environmental crypto-assets is the use of energy-efficient consensus mechanisms, such as Proof of Stake (PoS) or hybrid varieties, which do not require intensive use of computing power and specialized mining equipment, which significantly reduces their carbon footprint (Saleh 2021). In addition, pro-environmental crypto-assets are increasingly being designed in a way that allows for integration with sustainability and ESG standards, e.g. through tokenisation of environmental projects, carbon credits or financing pro-climate initiatives, which fits them into the broader context of green finance in the digital economy (OECD 2022). Sustainable development is defined as a concept that assumes that economic, social and environmental goals are simultaneously taken into account in the development process, while maintaining the possibility of meeting the needs of future generations (Misztal 2023). ESG (Environmental, Social, Governance), on the other hand, refers to a set of criteria used to assess the activities of companies and investments in terms of environmental, social and governance factors that may affect the risk, stability and financial performance of business entities (Oliver Yébenes 2024).

2. Research method

The aim of this study is to identify and analyze pro-environmental crypto-assets as a tool supporting sustainable development in the digital economy, with particular emphasis on the impact of the Proof of Work consensus mechanism on the natural environment. Due to the nature of the studied issue, covering both technological and economic and regulatory aspects, a qualitative approach was used, based on the analysis of secondary data sources (desk research). The study is of a review and analytical nature and was conducted on the basis of an analysis of the literature on the subject and available secondary sources on the environmental consequences of blockchain technology and cryptocurrencies. The aim of the study was to organize and synthetically present the most important aspects of the impact of the

Proof of Work (PoW) mechanism on the environment and to indicate alternative technological solutions described as more energy-efficient and pro-environmental.

The basic research method used in the article was the analysis of the literature on the subject, including scientific articles published in peer-reviewed international journals, reports of public institutions and international organizations, regulatory documents and industry analyses. The selection of literature was based on searching the Web of Science, Scopus and Google Scholar databases using the following keywords: cryptocurrencies, blockchain, energy consumption, carbon footprint, Proof of Work, Proof of Stake and sustainable finance. The analysis included publications from 2010–2025, which allowed to present both the initial stage of cryptocurrency development and the latest technological and regulatory trends. The analysis was structured in five main research areas concerning the impact of the Proof of Work mechanism on the environment and the socio-economic environment: consumption of natural resources, electricity consumption, carbon footprint, social and economic impact of PoW and electronic waste. Individual areas were analysed on the basis of criteria including the scale of energy use and technical infrastructure, the level of CO₂ emissions, the impact on local energy systems and social costs, and the degree of wear and tear of equipment used in the mining process. The adopted criteria made it possible to synthetically compare the environmental consequences of the functioning of cryptocurrencies based on the Proof of Work mechanism. This division was of an orderly nature and served to synthetically present the results of research available in the literature. The study also provides a general comparison of Proof of Work with alternative consensus mechanisms, such as Proof of Stake (PoS), primarily in terms of the declared level of energy intensity and potential environmental impact. This comparison was descriptive and based on the data presented in the analyzed sources.

3. Analysis of the environmental impact of PoW

The Proof of Work (PoW) mechanism, which is the basis for the functioning of the first generations of cryptocurrencies, is considered in the literature to be a key factor determining the environmental consequences of the development of blockchain technology. Blockchain as a technology can potentially support the achievement of sustainability goals, it is PoW-based networks that generate huge energy consumption (Kouhizadeh, Sarkins 2018). In accordance with the adopted research methodology, the analysis of the impact of PoW was carried out in a review and analytical approach by identifying, aggregating and grouping the results of empirical research and reporting analyses in five areas of environmental impact. The lack of a centralized, trusted authority means that blockchain needs a “consensus mechanism” to ensure trust across the network. In the case of bitcoin, consensus is reached through a method called “Proof-of-Work”, in which computers on the network – “miners” – compete with each other to solve a complex mathematical puzzle. Each attempt by a miner to solve it is called a “hash”, and the number of

attempts made by a miner in a second is called its “hashrate”. Once the puzzle is solved, the latest “block” of transactions is validated and added to the “chain” of transactions. The first miner to solve the puzzle is rewarded with new bitcoins and transaction fees on the network. The energy consumption of the bitcoin network is therefore both a security and a side effect of relying on the ever-increasing computing power of competing miners to validate transactions via PoW. (IEA 2019).

3.1. Consumption of natural resources

The PoW mechanism requires a continuous increase in the computing power of the network, which leads to intensive use of natural resources, in particular energy resources. The high energy intensity of PoW is conducive to the exploitation of fossil fuels, especially in regions where electricity is cheap but high-carbon (Truby 2018). A systematic review of the blockchain literature highlights that PoW is an example of a technology in which economic efficiency is achieved at the expense of the excessive use of environmental resources, which is contrary to the principles of a low-carbon economy (Kouhizadeh, Sarkins 2018).

Additional research indicates that the intensive use of resources in the PoW model is not limited to energy, but also includes the material resources necessary for the production of mining infrastructure. The life cycle of mining equipment is associated with a significant demand for rare earth metals and semiconductors, the extraction of which generates significant environmental burdens (Jones, Goodkind, Berrens 2022). PoW as a consensus mechanism does not have built-in incentives to optimize the use of resources, which distinguishes it from newer solutions designed in the spirit of environmental efficiency. As a consequence, PoW perpetuates the resource-intensive exploitation model characteristic of traditional energy-intensive sectors (Sedlmeir et al. 2020).

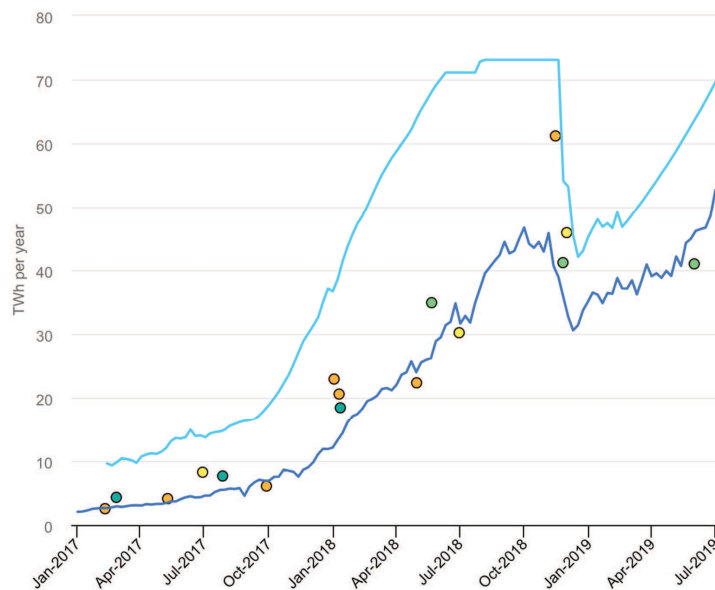
3.2. Electricity consumption

The electricity consumption of PoW networks is one of the best documented aspects of their environmental impact. Bitcoin’s energy demand is not related to the number of transactions processed, but to the level of mining difficulty and the competitive nature of the consensus mechanism (de Vries 2018). Data from the Cambridge Centre for Alternative Finance indicates that the annual energy consumption of the Bitcoin network is comparable to that of medium-sized countries, making PoW one of the most energy-intensive digital systems in the world (Blandin et al. 2020). Energy analyses indicate that the energy consumption of PoW networks is characterized by high volatility, but a long-term upward trend, related to the price of cryptocurrencies and the profitability of mining (Hayes 2017). A 2023 study found that energy consumption in cryptocurrency mining was around 0.5% of global electricity consumption. Bitcoin’s electricity consumption

varies depending on the study, the methodology adopted, and most studies are based on underestimating the price of electricity, electricity consumption is in the range of 37.7 TWh to 141.72 TWh, which is comparable to the annual energy demand of some medium-sized European countries (Laimon et al. 2025). A single transaction on the financial market using cryptoassets such as Bitcoin consumes about 1100 kWh, and Ethereum consumes over 80 kWh. A breakthrough in optimizing electricity consumption is the Proof of Stake model. It should be noted that the share of renewable energy sources used to acquire cryptoassets has been increasing in recent years, an increase of 60% in Bitcoin mining (CIRE.PL 2022).

Cryptocurrency mining has a positive and negative impact on the environment, the substitution effect is one of the positive effects, cryptoassets can replace currencies and financial systems, which reduces transaction costs, transport needs, and can contribute to increased investment in poorer countries. The production effect is linked to the process of mining cryptocurrencies, which requires significant energy consumption, mostly from fossil fuels, which causes an increase in CO₂ emissions. However, once mined, cryptocurrencies can replace traditional financial tools in transactions, leading to a positive environmental impact. To maximize the positive environmental impact of cryptoassets, it is essential to implement energy-efficient mining technologies and tighten regulations (Bashari et al. 2025).

Chart 1. Estimates of Bitcoin's energy consumption



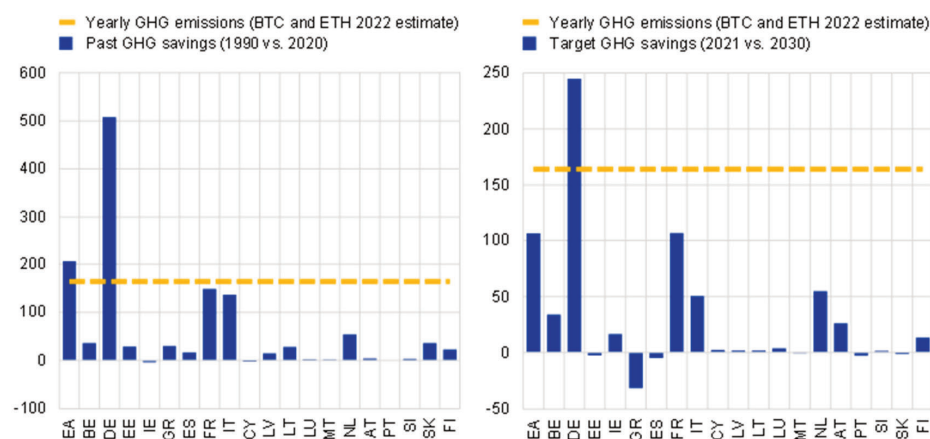
Source: IEA, Bitcoin energy use estimates, IEA, Paris 2020, <https://www.iea.org/data-and-statistics/charts/bitcoin-energy-use-estimates>, License: CC BY 4.0

3.3. Carbon footprint and CO₂ emissions

The high electricity consumption of PoW networks translates directly into significant greenhouse gas emissions. Bitcoin's carbon footprint is heavily dependent on the regional energy mix, and the dominance of fossil sources leads to significant CO₂ emissions (Stoll, Klaaßen, Gellersdörfer 2019). The further development of PoW-based cryptocurrencies may hinder the achievement of global climate goals if technological or regulatory changes are not implemented (Mora et al. 2018). Newer emission estimation models indicate that the PoW carbon footprint is often underestimated, as many analyses do not take into account indirect emissions related to the production of equipment and cooling infrastructure of mining centres. Bitcoin's annual global carbon emissions are in the range of 22.0 to 22.9 MtCO₂, which is comparable to the level of carbon emissions of Jordan and Sri Lanka. Bitcoin's approximate carbon footprint depicts a global problem and the need to address environmental externalities (Stoll, Klaaßen, Gellersdörfer 2019).

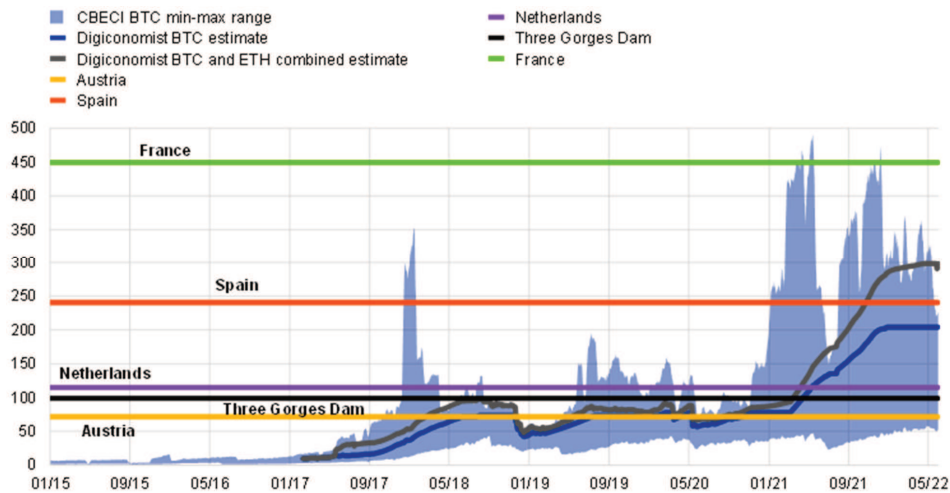
From July 2021 to January 2022, the energy consumption of cryptoassets increased by close to 67%, Bitcoin accounts for about 60% of the total energy consumption of cryptocurrencies. The share of renewables in Bitcoin mining decreased from 41.6% to 25.1% due to the crackdown on Chinese mines that used hydropower. The relocation of the mines to the U.S. and Kazakhstan increased carbon emissions from 478.27 gCO₂/kWh in 2020 to 557.76 gCO₂/kWh in 2021 using gas-based energy or coal-derived electricity (Sarkodie et al. 2024).

Chart 2. BTC and ETH's annual greenhouse gas emissions compared to previous greenhouse gas emissions savings and greenhouse gas emissions savings targets



Source: I. Gschossmann, A. van der Kraaij, P.-L. Benoit, E. Rocher, *Mining the environment – is climate risk priced into crypto-assets?*, "Macropprudential Bulletin, European Central Bank", vol. 18, 2022.

Chart 3. Estimated annual electricity consumption of global bitcoin (BTC) and etherum (ETH) compared to selected countries



Source: I. Gschossmann, A. van der Kraaij, P.-L. Benoit, E. Rocher, *Mining the environment – is climate risk priced into crypto-assets?*, “Macroeprudential Bulletin, European Central Bank”, vol. 18, 2022.

The data in the above graphs indicate significant carbon dioxide emissions at the level of most European Union countries in 2020. On the other hand, the estimated data for the period 2021–2030, for which a decrease in CO₂ emissions by some countries can be recorded. The share of carbon dioxide emissions from the blockchain sector will continue to be much higher than the 19 EU countries, which should be the direction of legislative changes in OECD forums. Estimates of the carbon footprint of bitcoin and etherum also show that their combined annual emissions as of May 2022 offset the current and target greenhouse gas (GHG) emissions savings in most eurozone countries. Electricity consumption is also high, consuming as much energy as some countries such as France, Spain or the Netherlands.

3.4. Social and economic impact of PoW

The environmental impact of PoW also has a social and economic dimension. In the regions where cryptocurrency mines are concentrated, there is an increase in electricity demand, which can lead to higher energy prices for local communities and businesses (de Vries 2018). PoW environmental costs are external costs that are not internalized in cryptocurrency prices. From an environmental economics perspective, this leads to an inefficient allocation of resources and fosters the perpetuation of business models that contradict the concept of sustainable development (Truby 2018). The negative environmental effects of PoW also

affect the social perception of blockchain technology, lowering the level of trust in its applications in the public and financial sectors (Kouhizadeh, Sarkis 2018). From a social perspective, it is indicated that sanctioned countries such as Iran or Russia can use cryptocurrency mining, in particular bitcoin, as a way to circumvent economic restrictions imposed to enhance international security. At the same time, intensive mining is associated with a high burden on energy systems, which can lead to destabilisation of power grids and power outages, examples of which have been recorded, for m.in example, in Tehran and Sukhumi, among others. Although the share of illegal activities in the total volume of bitcoin transactions remains relatively small at around 0.3% in 2020, cryptocurrencies are still used in activities such as money laundering or cybercrime, including ransomware attacks. There are also reports of their potential links to terrorist financing. Additional controversy is raised by the issue of the energy base of mining – the use of energy from regions where there is a risk of human rights violations, e.g. in the context of forced labor (Sapra, Shaikh, Dash 2023), is indicated.

3.5. Electronic waste

An important, but relatively less frequently analyzed aspect of the impact of PoW on the environment is the problem of electronic waste. Specialized mining equipment (ASICs) have a short life cycle, which leads to the generation of significant amounts of e-waste (Stoll, Klaaßen, Gallersdörfer 2019). Mining equipment becomes unusable after an average of 1.2 years, similar to fans left in mines, the approximate value of waste left behind is 5.1 million (Hossain, Steigner 2024). This waste is often difficult to recycle and can provide an additional source of environmental pollution, especially in countries with underdeveloped waste management systems (OECD 2020). According to a 2021 study, the annual amount of electronic waste derived from Bitcoin is 30.7 kilotons. E-waste is a threat to the environment on every level, from soil pollution to air and water pollution.

3.5.1. Analysis of selected cryptocurrencies based on the Proof of Work mechanism in terms of environmental impact

In this part of the study, a list of selected crypto-assets using the Proof of Work mechanism is made in order to show their diverse impact on the environment. The analysis includes projects of varying scale of popularity and degree of utilization of computing resources. The list allows you to capture the key differences between individual cryptocurrencies in terms of their environmental impact. The table shows a synthetic comparison of selected Proof of Work-based cryptocurrencies in terms of their environmental impact.

Table 1. Analysis of selected crypto-assets based on the Proof of Work mechanism in terms of environmental impact

Cryptoasset	Consumption of natural resources	Electricity consumption	Carbon footprint	Socio-economic impact	Electronic waste
Bitcoin (BTC)	Very high intensive utilization of ASIC hardware and cooling infrastructure	Very high	Very high	Rising energy costs and pressure on local energy systems	Very high rapid outdated mining equipment
Ethereum (before the Ethereum Merge)	High	High	High	DeFi market development with high network energy intensity	High
Litecoin (LTC)	High	High	High	Increase in energy demand in the mining process	High
Monero (XMR)	High-GPU/CPU-based mining	High	High	Greater transaction anonymity with high energy costs	Significant
Dogecoin (DOGE)	High	High	High	Speculative popularity generating an increase in mining activity	High
Bitcoin Cash (BCH)	Very high	Very high	Very high	Continuation of the PoW model with high environmental load	Very high
Ethereum Classic (ETC)	High	High	High	Maintaining an energy-intensive PoW model after the change of Ethereum to PoS	High

Source: own study.

The analysis indicates that crypto-assets using the Proof of Work mechanism are characterized by a high level of energy consumption and a significant environmental impact. The biggest burden is generated by Bitcoin, whose functioning is associated with very high electricity consumption, significant CO₂ emissions and a large amount of electronic waste resulting from the rapid obsolescence of ASIC equipment. Similar

trends are also observed in the case of Litecoin, Bitcoin Cash or Ethereum Classic, which continue the model based on an energy-intensive mining process. The analysis also shows that the development of the cryptocurrency market may increase pressure on local energy systems and increase energy costs in regions with a high concentration of crypto-asset mines. The results confirm that Proof of Work remains one of the most environmentally problematic solutions used in blockchain technology, reinforcing the importance of alternative consensus mechanisms such as Proof of Stake.

4. Green Cryptoassets – Technological and Economic Solutions

Pro-environmental crypto-assets are a response to the structural environmental constraints of Proof of Work-based cryptocurrencies and are increasingly being analyzed in the literature as part of the transformation of the digital economy towards sustainability compliance. Scientifically, the term refers to digital financial assets that use energy-efficient consensus mechanisms, are integrated with renewables, or are linked to environmental markets such as CO₂ emissions trading (Keskin 2022).

The basic technological solution underpinning green crypto-assets is to replace energy-intensive PoW algorithms with low-energy consensus mechanisms. Comparative studies indicate that Proof of Stake, Delegated Proof of Stake algorithms and BFT mechanisms are characterized by significantly lower energy consumption while maintaining the functionality of distributed networks (Rot, Zygała 2018). PoS stablecoins are based on validators selected based on the number of tokens held or delegated, this reduces energy consumption when verifying transactions (Koemtzopoulos, Zournatzidou, Sariannidis 2025).

An analysis of specific green crypto-asset projects illustrates how technological and economic innovations translate into real environmental impacts and energy markets. Bitcoin Minetrix is an example of a tokenized mining system that allows users to invest in computing power without the need for their own hardware. By centralizing mining and using modern data centers, this project reduces inefficient energy consumption and enables more controlled CO₂ emissions (CIRE. PL 2022). eTukTuk integrates blockchain into the electric mobility sector, tokenizing EV charging infrastructure and supporting decentralized energy trading. This system allows for the tracking and accounting of energy from renewable sources, increasing market transparency and enabling the financing of low-carbon projects (ZBIAM 2023). Cardano (ADA) uses a Proof of Stake (PoS) mechanism that reduces energy consumption by up to 99% compared to traditional Proof of Work, which has been confirmed in industry reports on cryptocurrency energy consumption (Bankier.pl 2024). With PoS, Cardano enables the creation of sustainable financial and energy applications, including tokenization of RES projects, without a large environmental burden. Solarcoin (SLR) is directly linked to solar energy production. Each token is awarded for a unit of energy produced from photovoltaic panels, which creates an economic incentive to invest in RES. Research shows that Solarcoin increases

the incentive to produce solar energy and improves the efficiency of photovoltaic investments in developing regions (Thanasi-Boçe, Hoxha 2025). Nano (XNO) uses a block-lattice structure, eliminating the need for energy-intensive consensus processes. This makes transactions almost energy-free, making Nano an example of a very environmentally friendly cryptocurrency, especially in digital payment systems (Business Insider 2026). Algorand (ALGO) combines Pure Proof of Stake with CO₂ offsetting, achieving carbon neutrality for the network. These mechanisms not only allow for minimizing energy consumption, but also support the implementation of ESG-compliant projects through automatic environmental impact reporting (Iberdrola 2024). BitGreen (BITG) in a hybrid model combines the functions of a medium of exchange with direct financing of pro-ecological initiatives. Part of the transaction fees is allocated to projects related to environmental protection and energy transition, which allows investors to make a real ecological contribution through the daily use of the grid (Money.pl 2022).

In order to illustrate the diversity of green crypto-assets, an analysis of selected projects using alternative consensus mechanisms and solutions to reduce the energy intensity of blockchain technology was carried out. Crypto-assets representing different approaches to sustainability were selected for the analysis, including both energy-efficient network mechanisms and projects supporting environmental activities. The benchmarks were primarily the consensus mechanism, the level of energy consumption and the energy efficiency characteristics of individual projects.

Table 2. Comparison of selected green crypto-assets in terms of consensus mechanism and environmental impact

Cryptoasset	Consensus mechanism	Estimated energy consumption	Energy efficiency characteristics	Potential limitations
Bitcoin Minetrix	Stake-to-Mine / PoS	Low compared to classic PoW	Reduce the need for traditional hardware mining	Early develop- ment project
eTukTuk	Proof of Stake	Low	Integrating blockchain with electromobil- ity and low-carbon transport	Limited scale of deployments
Cardano (ADA)	Proof of Stake	Very low	Energy-efficient Ouro- boros movement	Less decentrali- zation than PoW
SolarCoin (SLR)	Proof of Stake	Low	Supporting solar ener- gy production through a reward system	Low popularity of the project
Nano (XNO)	Open Represen- tative Voting	Very low	No energy-intensive mining	Limited market adoption

Source: own study.

The comparative analysis indicates that most of the surveyed projects are based on Proof of Stake consensus mechanisms or their variations, which are characterized by significantly lower energy consumption than the traditional Proof of Work mechanism. The Cardano, Nano and Algorand projects stand out for their particularly high energy efficiency, eliminating the need for an energy-intensive mining process. On the other hand, projects such as SolarCoin, BitGreen or eTukTuk combine technological functions with the implementation of specific environmental goals, supporting the development of renewable energy sources, electromobility and initiatives in line with the concept of sustainable development. The analysis is part of the contribution of our own study through a synthetic comparison and comparison of selected green crypto-assets in terms of their energy efficiency and potential impact on the implementation of sustainable development assumptions.

5. The importance of green crypto-assets for the financial market

The development of green crypto-assets has an indirect but multidimensional impact on the financial market, also affecting the energy-related stock market segment, in particular renewable energy. The mechanism of this impact is not homogeneous, but runs through several interdependent channels that reflect the increasing integration of digital finance with the energy transition and capital markets. One of the key channels of impact of green crypto-assets is their role as an alternative source of financing for renewable energy projects. Tokenization of energy assets and the use of blockchain make it possible to directly raise capital for investments in renewable energy sources, bypassing traditional intermediary institutions. The literature indicates that decentralized financing models can reduce transaction costs, shorten the time of raising capital and increase the availability of investments for a wider group of investors, including retail investors (Rot, Zygała 2018). In the long term, increased capital inflows into the RES sector may have a positive impact on the valuations of energy companies listed on stock exchanges, strengthening their market position.

The second important mechanism is the signalling function of green crypto-assets. The growing interest of investors in digital assets with a low environmental footprint can be interpreted as a signal of changing market preferences and the increasing importance of ESG environmental criteria in investment decisions. The financial literature emphasizes that the demand for ESG-compliant assets affects the structure of investment portfolios and the allocation of capital in the economy (Berg, Kölbel, Rigobon 2022). In this context, green crypto-assets can indirectly boost interest in shares of companies in the renewable energy sector, increasing their liquidity and stock market stability.

Another aspect of the impact of crypto-assets with limited environmental impact on the financial market is their impact on investor and corporate sustainability awareness. The integration of blockchain technology into energy and finance markets fosters the dissemination of information about the environmental impact of economic activity, which in turn may lead to a change in investment strategies. Increasingly, capital decisions take into account not only traditional financial ratios, but also environmental, social and governance (ESG) criteria, which are becoming an integral part of the valuation of companies (Zetzsche et al. 2020).

Summary

The development of blockchain technology and crypto-assets poses environmental challenges to the modern digital economy, primarily related to high energy consumption and greenhouse gas emissions in traditional Proof of Work consensus mechanisms. The analysis carried out in the article indicates that the impact of PoW includes not only energy intensity, but also social, economic and regulatory issues, which highlights the need to look for more sustainable technological solutions. Crypto-assets with a limited environmental impact are one of the possible responses to these challenges. They use consensus mechanisms with lower energy intensity, such as Proof of Stake, Pure Proof of Stake or hybrid models, and some projects also integrate functions related to supporting environmental initiatives and renewable energy sources.

An analysis of selected projects, such as Cardano, SolarCoin, Algorand, Nano, BitGreen, Bitcoin Minetrix or eTukTuk, suggests that crypto-assets with a limited environmental impact can contribute to reducing energy consumption compared to traditional PoW-based solutions. At the same time, some projects declare support for activities related to the energy transition and financing low-carbon initiatives. However, it should be emphasized that the true scale of this impact remains difficult to assess unequivocally due to the limited availability of comparable data and the dynamic development of the cryptocurrency market.

The literature also indicates that the development of crypto-assets with limited environmental impact has the potential to increase interest in ESG-based investments and support the development of the green finance market. Blockchain technology can also help increase transaction transparency and develop new financing models for environmental projects. At the same time, the development of this market segment faces numerous limitations, including the lack of uniform standards for reporting environmental impact, the risk of greenwashing, the immaturity of some technological solutions and regulatory diversity at the international level. Therefore, further research is needed on the actual environmental impact of crypto-assets with limited environmental impact, their economic efficiency and the possibilities for integration with climate policy and ESG-compliant financial instruments.

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