

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(6), 78-82.

Cryptocurrency Validation and Energy Transition in West Africa: A Comparative Analysis of PoW and PoS

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Received: 01 August 2026 **Accepted:** 14 October 2026 **DOI:** https://doi.org/10.32479/ijeep.25201

ABSTRACT

This study examines the energy sustainability of blockchain technologies in West Africa, focusing on cryptocurrencies validated through proof of work (PoW). Using an economic estimation method inspired by the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), international models are adapted to the specific realities of the West African Economic and Monetary Union (UEMOA). Data sources include national electricity pricing (Senelec, 2025), macroeconomic statistics (ANSD, 2023), regional monetary aggregates (BCEAO, 2023), and blockchain activity reports (Chainalysis, 2023). The analysis models daily energy consumption of crypto-mining in Dakar, Abidjan, and Lomé, and simulates adoption scenarios. Results show that converting only 5% of Senegal's M_1 money supply into PoW-based cryptocurrency would require energy equivalent to 144% of national demand, underscoring unsustainability. In contrast, proof of stake (PoS) reduces consumption by 99.95%, aligning blockchain adoption with energy transition goals. The paper highlights the need for proactive regulation, incentives for local innovation, and adapted energy governance to reconcile financial inclusion, digital sovereignty, and environmental responsibility. It provides a contextualized analytical framework relevant to policymakers, investors, and researchers engaged in sustainable technology development.

Keywords: Blockchain, Cryptocurrency, Energy Consumption, Sustainability
JEL Classifications: E22, E44, G11, Q4, O33

1. INTRODUCTION

The rise of blockchain technologies and cryptocurrencies is reshaping the contours of financial intermediation, particularly in emerging economies seeking digital sovereignty and monetary inclusion. In West Africa, this dynamic unfolds within a context of accelerated transformation in financial practices, driven by the dematerialization of transactions and the growing importance of digital services (BCEAO, 2022).

Yet behind the promises of a disintermediated, secure, and participatory financial system lies a strategic question: the energy sustainability of validation protocols, especially those based on proof of work (PoW). While effective in terms of security, this mechanism relies on massive electricity consumption, which is difficult to reconcile with the limited energy capacities of UEMOA countries (ANSD, 2023; Senelec, 2025).

The central issue of this study is therefore: to what extent are PoW-based cryptocurrency blockchains sustainable from an energy perspective in the West African context, and what technological alternatives could foster responsible and durable adoption?

To address this, we apply the economic estimation method of energy consumption inspired by the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), adapted to local realities. This approach is based on cross-analysis of regional data: Electricity pricing (Senelec, 2025), estimated mining revenues (Chainalysis, 2023), money supply (BCEAO, 2023), and national statistics

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(ANSD, 2023). It enables modeling of the energy footprint of crypto - mining in UEMOA's main activity zones.

The objective of this research, inspired by Mbaye (2025), is twofold: first, to realistically quantify the energy consumption induced by PoW blockchains in the region; second, to assess the potential benefits of transitioning to alternative protocols such as proof of stake (PoS), whose energy efficiency has been demonstrated (Ethereum Foundation, 2022).

Our main hypothesis is that while cryptocurrency blockchains promote inclusive and secure finance, their current PoW-based model generates an unsustainable energy footprint at scale. By contrast, adopting PoS offers a pathway more compatible with sustainability imperatives, technological sovereignty goals, and the energy constraints of African states. The article is structured into four sections: An introduction, a literature review, a modeling section, and a conclusion.

2. LITERATURE REVIEW

Cryptocurrency blockchain represents a major innovation in contemporary financial systems, redefining the notions of trust, traceability, and intermediation. Since Nakamoto's foundational work (Nakamoto's, 2008), academic literature has expanded considerably, addressing its economic, energy-related, and regulatory implications.

Early contributions to decentralized and digital payment systems can be traced back to the pioneering works of David (1981) and Wei (1998), who laid the foundations for anonymous and distributed electronic payment mechanisms. The emergence of Bitcoin and complementary currencies was subsequently discussed by Herlin (2013), while Storrer (2014) examined the legal implications of electronic money and virtual currencies.

Blundell-Wignall (2014) analysed Bitcoin both as a currency and as a trustless transfer technology, whereas Bollen (2016) discussed the legal status and regulatory challenges of online currencies. From a broader financial perspective, Guttmann and Plihon (2010) highlighted issues related to financial innovation and financial fragility. More recently, the Cambridge Centre for Alternative Finance (2024) has become a key reference for monitoring and assessing the energy consumption associated with cryptocurrency networks.

On the monetary and financial front, Brito and Castillo (2014), Rogojanu and Badea (2014), as well as Pluchart (2015) highlighted the potential of cryptocurrencies to foster financial inclusion and bypass traditional banking structures. More recently, Benbachir and El Haddad (2024) analyzed their impact on African banking systems, shedding light on issues of digital sovereignty and algorithmic disintermediation.

The energy question, long underestimated, has become central with the widespread use of the proof of work (PoW) validation mechanism. Digiconomist (2024) and Boulet (2021) proposed empirical indicators to quantify Bitcoin's energy footprint, while Yahanpath (2014) and CBECI (2024) developed economic estimation models based on mining revenues and electricity costs. In 2025, Diallo and Mensah deepened this approach by applying it to African contexts, underscoring the structural limitations of power grids in meeting mining demands.

The transition toward more energy-efficient protocols, such as proof of stake (PoS), is generating growing interest. The Ethereum Foundation (2022) demonstrated a 99.95% reduction in energy consumption after the Merge, a finding confirmed by Chen and Vivek (2014), Dodgson and Gann (2015), and more recently by N'Diaye and Sow (2025), who advocate for the strategic adoption of PoS in countries with limited energy capacity.

On the regulatory side, Greebel et al. (2015), Nellen (2015), and Ali et al. (2014) emphasized the need for legal frameworks adapted to crypto-assets. In 2024, the OECD and the African Union published convergent reports calling for harmonization of regulatory frameworks to secure usage and mitigate risks of volatility and money laundering.

Finally, the works of Chabal (2017), Cusumano (2014), Raskin (2014), and Raymaekers (2015) enrich the debate on cryptocurrency volatility, legal status, and integration into asset portfolios. In 2025, Koffi and Traoré proposed a typology of crypto uses in Francophone Africa, highlighting informal dynamics and community-based trust mechanisms.

This review underscores the complexity of issues surrounding cryptocurrency blockchain, justifying a multidisciplinary approach that combines economics, energy, technology, and regulation. It sheds light on adoption trajectories in UEMOA countries, at a time when digital transformation must be aligned with sustainability objectives.

3. ECONOMIC MODELING OF ENERGY CONSUMPTION IN BLOCKCHAIN NODES AND RESULTS

The energy consumption of blockchains (particularly those based on the proof of work (PoW) validation mechanism) represents a critical issue at the intersection of technological, economic, and ecological dimensions.

3.1. Conceptual Framework

In this study, we adopt an economic estimation approach inspired by the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024) and Yahanpath (2014), while adapting it to the specificities of the UEMOA region. The choice of this model is pragmatic: it links observable economic variables such as mining revenues, electricity costs, and money supply to technological and environmental dynamics. This approach helps overcome the opacity of technical data, which is often difficult to obtain, while providing a contextualized reading suited to the West African framework.

Several models already exist in the economic literature, including:

- Technical direct measurement models (Krause and Tolaymat,

2018; Stoll et al., 2019), which rely on analyzing hashrates, machine efficiency, and mining infrastructure. While technically precise, they require data often unavailable in emerging economies

- Hybrid energy models (Gallersdörfer et al., 2020), which combine technical data with economic assumptions but remain focused on large economies where mining infrastructures are massive and well-documented. Their transposition to the African context is limited
- Environmental carbon footprint models (De Vries, 2018; Mora et al., 2018), which emphasize ecological externalities by estimating CO_2 emissions linked to mining. These are essential for assessing sustainability but do not directly evaluate the economic capacity of actors to bear energy costs.

By comparison, the economic model used in this article has a dual strength: theoretical, as it draws on literature directly linking economic performance and technological sustainability (Yahanpath, 2014; CBECI, 2024); and empirical, as it uses reliable local data (Senelec, ANSD, BCEAO, Chainalysis) adapted to UEMOA's energy and monetary realities.

This approach not only estimates blockchain energy consumption but also evaluates sustainability in a context where electrical infrastructures are limited. Unlike purely technical or environmental models, the economic model offers an integrated perspective that connects innovation, costs, and local constraints.

In short, the use of this model is justified by its ability to provide realistic and contextualized estimates. Where other models offer partial insights (technical or ecological), it proposes a holistic vision that articulates economics, technology, and ecology; essential for anticipating blockchain adoption trajectories in West Africa.

This method rests on the hypothesis that mining revenues determine miners' ability to bear energy costs, and that the share of revenues allocated to electricity can be used to estimate the network's overall energy consumption. This approach bypasses the inaccessibility of technical data by mobilizing observable and measurable economic variables.

3.2. Analytical Approach

The modeling process unfolds in the following steps:

- Estimating the average electricity cost in high mining activity zones (Dakar, Abidjan, Lomé), based on Senelec (2025) and regional averages (ANSD, 2023)
- Evaluating daily mining revenues based on extracted cryptocurrency volumes and their average valuation (Chainalysis, 2023)
- Defining a standard assumption on the share of revenues devoted to energy, set at 60%, in line with Cambridge model assumptions
- Applying the following estimation formula:

Energy Consumption (kWh) = Mining Revenues × Energy Share/Average Cost/kWh

Table 1: Data sources used for energy sustainability analysis in UEMOA

Sources	Data used	Year
Senelec	Energy pricing	2025
ANSD	Macroeconomic statistics	2023
BCEAO	M_1 money supply	2023
Chainalysis	Regional blockchain activity	2023
Ethereum foundation	Comparative PoW/PoS data	2022

Source: Compiled by the author from official datasets and institutional reports

This formula enables simulation of different adoption scenarios by integrating prospective assumptions on monetary conversion (5% of M_1) and comparing results between PoW and PoS protocols.

3.3. Data Sources

Data sources used for energy sustainability analysis in UEMOA is presented in Table 1.

3.4. Basic Assumptions

The key variables, assumptions, and retained parameter values used in the energy consumption model are summarized in Table 2.

This article situates itself at the crossroads of technological, economic, and environmental dimensions. The Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024) has shown that mining revenues are relevant indicator for estimating actors' capacity to bear energy costs.

Starting from this hypothesis, it becomes possible to directly link observable economic variables (such as generated revenues and electricity costs) to estimates of overall energy consumption, while bypassing the opacity of often inaccessible technical data.

Yahanpath (2014) reminds us that the evaluation of emerging technologies cannot be limited to technical performance alone: it must also integrate economic and environmental externalities to assess sustainability. This is why using data from Senelec (2025) and ANSD (2023) on energy costs and macroeconomic statistics anchors the modeling in UEMOA's real context. BCEAO (2023) data on the M1 aggregate provide a solid basis for simulating prospective adoption scenarios, while Chainalysis (2023) reports offer empirical measures of regional blockchain activity. Finally, PoW versus PoS comparisons from the Ethereum Foundation (2022) enrich the analysis by introducing a forward-looking perspective on protocol evolution.

Thus, the use of these data is not incidental. It follows a theoretical logic that links economic variables to technological and environmental dynamics. It scientifically justifies the estimation of blockchain energy consumption and evaluates the sustainability of its adoption in the West African context.

Empirically, the choice of data responds to a need for relevance and contextualization. Information from Senelec (2025) and ANSD (2023) anchors energy cost estimates in regional reality, accounting for tariffs and macroeconomic statistics specific to UEMOA. BCEAO (2023) data on M_1 money supply provide a reliable basis for simulating cryptocurrency adoption scenarios, while Chainalysis (2023) reports offer concrete measures of regional blockchain activity and mining revenues. Finally, PoW

Table 2: Key variables and retained values for energy consumption modeling in UEMOA

Variables	Retained values	Justifications
Average electricity cost	85 FCFA/kWh	UEMOA average (Senelec/ANSD)
Daily mining revenues	120 million FCFA	Conservative estimate (Chainalysis, 2023)
Share of revenues for energy	60%	Standard assumption (CBECI, 2024)

Source: Author's compilation based on Senelec (2025), ANSD (2023), BCEAO (2023), Chainalysis (2023), and CBECI (2024)

Table 3: Comparative energy consumption of PoW and PoS in the UEMOA context

Criterion	PoW	PoS
Consumption (kWh/day)	31,764,706	15,882
Percentage of national consumption	144	0.07
Estimated energy cost	1.9 billion FCFA/day	1.35 million FCFA/day
Sustainability	Low	High

Source: Author's calculations based on CBECI (2024), Senelec (2025), ANSD (2023), BCEAO (2023), Chainalysis (2023), and Ethereum Foundation (2022)

versus PoS comparisons from the Ethereum Foundation (2022) enrich the analysis by introducing a technological and prospective dimension to protocol evolution.

By using these sources, the study relies on empirical data that reflect both local energy constraints and global blockchain dynamics. This approach ensures that the proposed model faithfully mirrors the economic and technological reality of the West African context.

3.5. Proof of Work (PoW) Validation Scenario

- Estimated energy consumption: 120,000,000 × 60%/85 = 847,059 kWh/day
- Share of national consumption: = 3.84% of Senegal's electricity demand (22 million kWh/day).

3.6. Prospective PoW Scenario: Crypto Adoption at 5% of Money Supply

- Senegal's M_1 money supply: 9,000 billion FCFA
- 5% converted into crypto: 450 billion FCFA
- Estimated daily volume: 4.5 billion FCFA
- PoW consumption: 4,500,000,000 × 0.60/85 = 31,764,706 kWh/day
- Result: Energy impact = 144% of national consumption, highlighting the clear unsustainability of PoW.

3.7. Alternative Scenario: Proof of Stake (PoS) Validation

- Estimated energy reduction: 99.95%
- PoS consumption: 31,764,706 × 0.0005 = 15,882 kWh/day
- Result: Strong sustainability under PoS.

A comparative synthesis of the estimated energy consumption, economic costs, and sustainability outcomes under both Proof of Work and Proof of Stake protocols is presented in Table 3.

4. DISCUSSION AND ECONOMIC POLICY IMPLICATIONS

The results of this study reveal a structural tension between the ambition to integrate blockchain technologies into West African economies and the energy constraints that limit their sustainability. The proof of work (PoW) adoption scenario, applied to just 5% of Senegal's M_1 money supply, generates energy consumption equivalent to 144% of the country's daily national demand. This underscores the mismatch between PoW's energy requirements and the capacities of regional electrical infrastructures (Senelec, 2025; ANSD, 2023).

Faced with this impasse, transitioning to more energy-efficient validation protocols such as proof of stake (PoS) appears not only desirable but necessary. With an estimated 99.95% reduction in energy consumption (Ethereum Foundation, 2022), PoS offers a credible alternative to reconcile technological innovation with environmental responsibility. However, this transition requires a multidimensional support strategy.

Three key action areas emerge:

- Regulatory: Establishing a clear legal framework for crypto-assets, exchange platforms, and validation mechanisms to channel innovation while managing systemic risks
- Technological: States must encourage the development of local solutions (sovereign blockchains, solar-powered mining, PoS infrastructures) adapted to the region's energy and digital realities
- Economic and geopolitical: Digital sovereignty requires reducing dependence on foreign infrastructures and mastering technological value chains.

In sum, integrating blockchain technologies within UEMOA cannot be envisioned without proactive energy governance, adapted regulation, and an innovation strategy rooted in sustainable development priorities. This study thus invites policymakers, investors, and researchers to rethink technological adoption trajectories in light of ecological imperatives and economic sovereignty.

5. CONCLUSION

The analysis conducted in this article highlights the growing tensions between technological innovation and energy sustainability in the West African context. By applying an economic estimation method based on updated regional data (Senelec, 2025; ANSD, 2023; BCEAO, 2023; Chainalysis, 2023), we demonstrated that large-scale adoption of PoW-based blockchains would result in energy consumption far beyond the current electrical capacities of UEMOA countries. The prospective scenario (simulating the conversion of 5% of Senegal's M_1 aggregate into PoW cryptocurrency) reveals an energy demand equivalent to 144% of daily national consumption, underscoring an unsustainable trajectory.

Conversely, adopting alternative protocols such as proof of stake (PoS) would reduce this footprint by 99.95%, paving the way for a more responsible integration of blockchain technologies. These

findings call for a strategic reconfiguration of public policies built around three levers: proactive regulation of crypto-assets, incentives for local innovation (particularly in green mining and sovereign blockchains), and energy governance aligned with ecological transition goals.

Beyond the case of blockchain, this study illustrates the relevance of economic analysis tools in anticipating the environmental externalities of emerging technologies. It invites researchers, policymakers, and investors to place sustainability at the heart of innovation trajectories in order to build an African digital ecosystem that is inclusive, resilient, and ecologically sustainable.

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