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Energy Sustainability of Cryptocurrencies in Africa: The PoW - PoS Dilemma

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Abstract

Blockchain adoption in Africa raises critical concerns about energy sustainability and systemic financial risks. In West Africa, digital finance is promoted as a driver of monetary inclusion and sovereignty, yet Proof of Work (PoW) blockchain validation imposes unsustainable energy costs with direct implications for transaction efficiency, monetary stability, and systemic resilience. This study applies an economic modeling framework inspired by the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), integrating regional data on electricity pricing (Senelec, 2025), monetary aggregates (BCEAO, 2023), and blockchain activity (Chainalysis, 2023). Results show that converting 5% of Senegal's M1 into PoW validated cryptocurrency transactions would require 144% of national electricity demand, confirming incompatibility with financial stability. Comparative analysis of Nigeria, South Africa, Kenya, and Ghana highlights heterogeneous vulnerabilities but a shared unsustainability of PoW. Policy implications emphasize coordinated regulation, technological innovation, and energy governance. Proof of Stake (PoS), reducing energy use by 99.95%, emerges as a credible pathway for sustainable blockchain integration in emerging economies.

JEL classification: E22, E44, G11, Q4, O33.
Keywords: Blockchain, cryptocurrency, Energy consumption, Sustainability.

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1. Introduction

The rise of blockchain technologies and cryptocurrencies is reshaping financial intermediation mechanisms, particularly in emerging economies where monetary inclusion and digital sovereignty are strategic priorities. In West Africa, this dynamic unfolds within a context of accelerated transformation of financial practices, driven by the dematerialization of cryptocurrency transactions and the rapid expansion of digital services (BCEAO, 2022).

Yet, behind the promises of a decentralized and secure financial system lies a major constraint: the energy sustainability of blockchain validation protocols, especially those based on Proof of Work (PoW). While recognized for its robustness in terms of security, this mechanism relies on massive electricity consumption, hardly compatible with the limited energy capacities of UEMOA countries (ANSD, 2023; Senelec, 2025). The tension between financial innovation and structural constraints of African energy systems thus constitutes the core of the research problem.

This study examines the energy sustainability of PoW-based blockchains in the West African context and explores technological alternatives such as Proof of Stake (PoS), which may enable responsible adoption. To address this, we employ an estimation method inspired by the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), adapted to local realities. The approach combines regional data on electricity pricing (Senelec, 2025), estimated mining activity revenues (Chainalysis, 2023), monetary aggregates (BCEAO, 2023), and macroeconomic statistics (ANSD, 2023), allowing us to model the energy footprint of crypto-mining activity in UEMOA, while opening the door to pan-African comparisons.

The objective is twofold: first, to realistically quantify the energy consumption induced by PoW blockchains; second, to assess the potential benefits of transitioning to alternative protocols such as PoS, whose energy efficiency has been demonstrated (Ethereum Foundation, 2022). The central hypothesis is that, although blockchains foster inclusive and secure finance, their current PoW-based model generates an unsustainable footprint at scale. Conversely, PoS appears more compatible with sustainability imperatives and the technological sovereignty goals of African states. This study provides a contextualized estimation of blockchain-related energy costs, directly linking them to the monetary aggregates and energy infrastructures of the UEMOA region, thereby offering an original contribution to applied economics. By adapting international models (CBECI, Ethereum Foundation) to African realities, the article delivers insights that are transferable to other emerging economies facing similar tensions between innovation and sustainability.

The article is structured into four sections: introduction, literature review, modeling, and conclusion.

2. Literature Review

Cryptocurrency-based blockchain has become a major innovation in contemporary financial systems, reshaping trust, traceability, and intermediation. Since Nakamoto's (2008) seminal work, the literature has expanded to monetary, energy, and regulatory dimensions. Early studies (Brito & Castillo, 2014 ; Rogojanu & Badea, 2014 ; Pluchart, 2015) emphasized the potential of cryptocurrencies to foster financial inclusion and bypass traditional banking structures, while recent African research highlights issues of digital sovereignty and algorithmic disintermediation (Benbachir & El Haddad, 2024). CFRI has reinforced this debate by publishing analyses on financial resilience and inclusion through digital services, confirming the relevance of blockchain in financial modernization trajectories.

Energy sustainability has become central with the dominance of Proof of Work (PoW). Empirical indicators (Digiconomist, 2024 ; Boulet, 2021) and estimation models (Yahanpath, 2014 ; CBECI, 2024) quantify Bitcoin's footprint, while Diallo & Mensah (2025) highlight the structural limits of African electricity grids. CFRI has contributed to this field with studies on forecasting returns of clean-energy related stocks (Xinling Liu, Binjie Wang, Jianhao Xue, Qunwei Wang, Xingyu Dai & Xuan-Hoa Nghiem, 2025) and on energy diversification and financial development (Thanh Nguyen, Son Nghiem & Anh-Tuan Doan, 2025), offering comparative frameworks for assessing cryptocurrency sustainability.

The transition toward energy-efficient protocols such as Proof of Stake (PoS) is gaining momentum. The Ethereum Foundation (2022) demonstrated a 99.95% reduction in energy consumption after the Merge, a finding echoed by N'Diaye & Sow (2025). CFRI, through articles on green finance and new productive forces (Mirza, Umar, Lobont & Safi, 2025), validates PoS as a credible pathway for emerging economies. On regulation, earlier works (Ali & Barrdear, 2014 ; Nellen, 2015) stressed the need for tailored frameworks, while OECD and African Union reports (2024) call for harmonization to mitigate volatility and illicit flows. CFRI has published analyses on cryptocurrency regulation and financial governance in China, offering comparative insights relevant to African policymakers.
Finally, studies on volatility, legal status, and portfolio integration (Chabal, 2017 ; Raskin, 2014 ; Raymaekers, 2015) enrich the debate, while Koffi & Traoré (2025) propose a typology of crypto uses in Francophone Africa, highlighting informal dynamics and community trust. Beyond these dimensions, recent contributions emphasize that the sustainability of cryptocurrencies cannot be considered independently of market dynamics. Mining revenues and economic incentives are directly shaped by price formation processes and trading conditions. Fassas, Papadamou & Koulis (2020), for example, show that Bitcoin futures play a significant role in price discovery, underscoring the importance of derivative markets alongside spot trading. Integrating these insights provides a more comprehensive economic context, as fluctuations in valuation and market structures directly influence transaction volumes, miners' profitability, and ultimately the energy sustainability of blockchain adoption.

3. Economic modelling of energy consumption at blockchain nodes

The energy consumption of blockchains (particularly those that rely on the Proof of Work (PoW) consensus mechanism) constitutes a critical issue at the intersection of technological, economic and environmental 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), adapted to the specific conditions of the UEMOA region. This pragmatic modelling choice links observable economic variables (mining activity revenues, electricity costs, and monetary aggregates) to technological and environmental dynamics. By doing so, the approach helps to overcome the opacity of technical data, which are often difficult to obtain, while providing a contextualized interpretation suited to the West African setting.

Several modelling strategies already exist in the economic literature, notably:

- Direct technical measurement models (Krause & Tolaymat, 2018; Stoll, Klaaßen & Gallersdörfer, 2019), which rely on analysis of hash rates, hardware efficiency and mining infrastructure. Although technically precise, these models require data that are frequently unavailable in emerging economies.
- Hybrid energy models (Gallersdörfer, Klaaßen & Stoll, 2020), which combine technical data and economic assumptions but remain focused on large economies where mining infrastructures are extensive and well documented; their transferability to the African context is therefore limited.
- Environmental carbon-footprint models (de Vries, 2018; Mora et al., 2018), which emphasize ecological externalities by estimating CO2 emissions associated with mining. These contributions are essential for assessing sustainability but do not directly evaluate the economic capacity of actors to bear energy costs.

By contrast, the economic model employed in this article has a twofold strength: theoretical, insofar as it builds on literature that directly links economic performance to technological sustainability (Yahanpath, 2014; CBECI, 2024); and empirical, because it draws on reliable local data sources (Senelec, ANSD, BCEAO, Chainalysis) that are appropriate to the energy and monetary realities of the UEMOA.

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

In summary, the use of this model is justified by its capacity to deliver realistic, contextualized estimates. While other models provide partial perspectives (technical or ecological), the present framework proposes a comprehensive view that articulates economic, technological and ecological dimensions; an essential basis for anticipating blockchain adoption trajectories in West Africa.

The method rests on the hypothesis that miners' revenues determine their capacity to absorb energy costs, and that the share of revenues allocated to electricity can be used to estimate the network's overall energy consumption. By mobilizing observable and measurable economic variables, this approach circumvents the inaccessibility of detailed technical data.

3.2 Analytical approach

The modelling procedure proceeds as follows:

- Estimate the average electricity price in high-mining-activity areas (Dakar, Abidjan, Lomé), using Senelec (2025) and regional averages (ANSD, 2023).
- Assess daily mining activity revenues based on mined cryptocurrency volumes and their average valuation (Chainalysis, 2023).
- Adopt a standard assumption for the share of mining activity revenues allocated to energy costs, set at 60%, in line with the Cambridge model.
- Apply the following estimation formula to derive energy consumption:

Energy consumption (kWh/day) = Daily mining activity revenue (local currency) x Energy share / Average electricity price (local currency / kWh)

This formula enables simulation of alternative adoption scenarios by incorporating forward-looking assumptions on currency conversion (for example, conversion of 5% of M1 into cryptocurrency) and by comparing outcomes across consensus protocols (PoW versus PoS).

3.3 Data sources

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

Source	Data used	Year
Senelec	Electricity tariffs	2025
ANSD	Macroeconomic statistics	2023
BCEAO	Monetary aggregate M1	2023
Chainalysis	Regional blockchain activity	2023
Ethereum Foundation	PoW/PoS comparative data	2022

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

3.4 Core assumptions

The article sits at the intersection of technological, economic and environmental dimensions. The Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024) indicates that mining revenues are a relevant indicator for estimating miners' capacity to bear energy costs. From this premise, observable economic variables (such as revenues and electricity prices) can be directly linked to estimates of total network energy consumption, thereby circumventing the frequent unavailability of detailed technical data.

Table 2: Key variables for modelling energy consumption in UEMOA

Variable	Value used	Justification
Average electricity price	85 FCFA/kWh	UEMOA average (Senelec / ANSD)
Daily mining activity revenues	120,000,000 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).

The daily mining activity revenue of 120 million FCFA is derived from Chainalysis (2023) data on regional blockchain activity. Specifically, Chainalysis reports an average monthly mining-related transaction volume of approximately 3.6 billion FCFA in West Africa. Dividing this monthly figure by 30 days yields an estimated daily revenue of 120 million FCFA. This value is described as a conservative estimate because it reflects an average baseline rather than peak market conditions, thereby ensuring robustness in the modelling framework.

Yahanpath (2014) reminds us that the evaluation of emerging technologies must go beyond technical performance and incorporate economic and environmental externalities to assess sustainability. Accordingly, the use of Senelec (2025) and ANSD (2023) data on energy costs and macroeconomic statistics grounds the modelling in the real UEMOA context. BCEAO (2023) figures for M1 provide a robust basis for simulating potential adoption scenarios, while Chainalysis (2023) reports supply empirical measures of regional blockchain activity and mining revenues. Finally, PoW versus PoS comparisons from the Ethereum Foundation (2022) introduce a forward-looking perspective on protocol evolution.

Using these sources is therefore not ancillary: it follows a theoretical logic that links economic variables to technological and environmental dynamics and scientifically justifies the estimation of blockchain energy consumption and the assessment of adoption sustainability in the West African context. Empirically, the data selection responds to the need for relevance and contextualization. Senelec (2025) and ANSD (2023) anchor energy-cost estimates in regional reality by accounting for tariffs and macroeconomic statistics specific to UEMOA. BCEAO (2023) M1 data enable credible simulations of cryptocurrency adoption scenarios, while Chainalysis (2023) provides concrete measures of regional blockchain activity and mining activity revenues. PoW vs. PoS comparisons from the Ethereum Foundation (2022) add a technological and prospective dimension to protocol evolution. By relying on these sources, the study draws on empirical evidence that reflects both local energy constraints and global blockchain dynamics, ensuring that the proposed model faithfully represents the economic and technological realities of the West African context.

3.5 Proof of Work (PoW) blockchain validation scenario

- Estimated energy consumption:
  120,000,000 x 60% / 85 = 847 059 kWh/day
- Share of national consumption (Senegal): this baseline corresponds to 3.84% of the country's daily electricity demand (assumed here as 22 million kWh/day).

The national daily electricity demand for Senegal is assumed at 22 million kWh/day, derived from official annual statistics (ANSD, 2023; Senelec, 2025). This figure results from dividing the reported annual consumption by 365 days, thereby providing a consistent baseline for percentage calculations in the PoW scenario.

3.6 Potential PoW adoption scenario: conversion of 5% of M1 into cryptocurrency

- Monetary aggregate (M1, Senegal): 9 000 billion FCFA.
- 5% conversion to crypto: 450 billion FCFA.
- Estimated daily transaction volume (simple pro-rata): 4.5 billion FCFA/day.
- Estimated PoW energy consumption (daily):

Energy (kWh / day) = 4,500,000,000 x 0.60 / 85 = 31 764 706 kWh/day

- Result (interpretation): the computed energy requirement equals 144% of Senegal's assumed daily electricity consumption, indicating that a PoW-based adoption at this scale would be clearly unsustainable under the stated assumptions.

The estimated daily transaction volume of 4.5 billion FCFA/day is derived from the aggregate conversion of 450 billion FCFA (5% of M1) into cryptocurrency. The calculation assumes an average turnover rate of 1% per day, equivalent to a holding period of approximately 100 days. In other words, it is hypothesized that 1% of the converted stock circulates daily through transactions. This simplifying assumption, inspired by liquidity patterns reported in Chainalysis (2023), provides a transparent link between the aggregate conversion figure and the daily transaction flow used in the energy consumption model.

Table 3: Sensitivity of PoW daily energy consumption to energy share (α) and electricity price (c) (Senegal, 5% of M1 scenario)

Energy share α	Price c (FCFA/kWh)	Energy (kWh/day)	% of national consumption (Senegal)
0.40	50	36,000,000	163.6%
0.40	85	21,176,471	96.3%
0.40	120	15,000,000	68.2%
0.60	50	54,000,000	245.5%
0.60	85	31,764,706	144.4%
0.60	120	22,500,000	102.3%
0.80	50	72,000,000	327.3%
0.80	85	42,352,941	192.5%
0.80	120	30,000,000	136.4%

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

- Baseline daily mining activity revenue R = 4,500,000,000 FCFA (5% of M1 scenario).
- Formula used: E = Rα / c
- Assumption for Senegal's national daily electricity demand: 22,000,000 kWh/day.
- Values rounded to the nearest whole number.

The sensitivity grid reported in Table 3 confirms the robustness of the main result: across a wide and plausible range of the energy-share parameter (α) and of average electricity prices (c), a PoW deployment equivalent to 5% of M1 exerts a very large pressure on Senegal's power system. Even under conservative assumptions (α = 0.40) and (c = 120 FCFA/kWh), estimated PoW consumption reaches 68% of national daily demand; for the baseline parameters used in the paper (α = 0.60), (c = 85 FCFA/kWh) the requirement attains = 144%, matching the central finding. These results show that the conclusion of PoW's unsustainability is not an artefact of a single parameter choice but holds for realistic parameter combinations. Policy implications follow: beyond privileging energy - efficient consensus mechanisms (PoS), any consideration of blockchain adoption at scale must be accompanied by explicit energy - capacity planning, targeted investments in renewables and regional cooperation to mitigate systemic risks highlighted by the sensitivity analysis.

3.7 Alternative scenario: Proof of Stake (PoS) validation

- Estimated energy reduction (PoS vs PoW): 99.95% (Ethereum Foundation, 2022, used here as a benchmark).
- PoS daily consumption (derived): 31 764 706 x 0.0005 = 15 882 kWh/day
- Result (interpretation): under the same monetary conversion scenario, PoS reduces energy demand to a negligible share of national consumption, implying strong sustainability relative to PoW.

Table 4: Comparative energy and cost metrics - UEMOA (Senegal)

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

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

Table 5: Pan-African comparison

Country	M1 (approx.)	5% conversion (FCFA)	Estimated PoW consumption (kWh/day)	% of national consumption	Estimated PoS consumption (kWh/day)	Relative sustainability
Senegal	9,000 bn FCFA	450 bn FCFA	31,764,706	144%	15,882	Very low (PoW); high (PoS)
Nigeria	45,000 bn FCFA	2,250 bn FCFA	158,823,529	65%	79,412	Moderate pressure; PoS sustainable
South Africa	60,000 bn FCFA	3,000 bn FCFA	211,764,706	40%	105,882	Lower pressure; PoS sustainable
Kenya	12,000 bn FCFA	600 bn FCFA	42,352,941	80%	21,176	High vulnerability; PoS necessary
Ghana	15,000 bn FCFA	750 bn FCFA	52,941,176	90%	26,470	High pressure; PoS indispensable

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

This analytical framework equips policymakers, investors, and researchers with tools to anticipate the energy externalities of financial innovations and to guide sustainable development trajectories.

3.8 Limitations of the PoW and PoS scenarios

The scenario analysis conducted in this study provides indicative insights into the energy implications of blockchain adoption in West Africa. Nevertheless, several limitations must be acknowledged for both PoW and PoS scenarios. First, the results are highly sensitive to parameter choices, including electricity prices, the share of mining revenues allocated to energy costs, and the assumed national electricity demand (22 million kWh/day for Senegal). These values are derived from annual statistics and stylized assumptions, and may vary across time, regions, and seasons. Second, the estimation of daily transaction volumes (4.5

billion FCFA/day in the 5% M1 scenario) relies on a simplified turnover assumption of 1% per day, equivalent to a holding period of 100 days.
While inspired by liquidity patterns reported in Chainalysis (2023), this assumption may not fully capture the heterogeneity of transaction behaviors. Third, the PoS scenario, although demonstrating a 99.95% reduction in energy consumption, is based on benchmark data from the Ethereum Foundation (2022) and may not be directly transferable to other blockchain ecosystems or regional infrastructures. Moreover, the model does not account for indirect energy costs such as data-center operations, cooling requirements, or network expansion. Finally, both scenarios focus primarily on energy consumption and do not integrate broader ecological, financial, or socio-economic externalities. These caveats suggest that the results should be interpreted as indicative rather than definitive, and that policy conclusions must be framed with caution, taking into account the uncertainties inherent in the modelling framework.

4. Discussion and policy implications

The numerical scenarios highlight a structural tension between ambitions to deploy blockchain-based financial infrastructures and the limited electrical capacity of many West African economies. A PoW adoption equivalent to 5% of Senegal's M1 would, under the present assumptions, require energy in excess of national supply (144% of daily demand), demonstrating a fundamental incompatibility between large-scale PoW deployment and regional energy constraints. The pan-African comparison confirms heterogeneous but widespread vulnerability: even larger economies face substantial pressure under PoW, while PoS consistently reduces energy exposure to negligible levels.

Policy priorities:

1. Regulation: Develop harmonized legal frameworks for crypto-assets, exchanges and consensus mechanisms to mitigate systemic and illicit-flow risks.
2. Technology: Promote energy-efficient architectures (PoS, permissioned sovereign chains) and support local R&D and renewable-powered infrastructures where appropriate.
3. Economic and geopolitical strategy: Strengthen digital sovereignty through capacity building, regional cooperation and strategic partnerships that enable technology transfer and shared governance of energy-intensive infrastructures.

The results highlight the necessity of integrating energy considerations into monetary and regulatory policies, in order to reconcile financial inclusion, digital sovereignty, and ecological transition. Integrating blockchain technologies in the UEMOA requires proactive energy governance, coordinated regulation and innovation strategies aligned with sustainable development objectives. Policymakers, investors and researchers should therefore prioritize protocol choices and institutional arrangements that reconcile financial inclusion goals with ecological and energy constraints.

5. Conclusion

This study reveals a structural mismatch between ambitions to deploy blockchain-based financial infrastructures and the actual energy capacities of many African economies. Under a conservative scenario in which 5% of M1 is converted into cryptocurrency, Proof of Work (PoW) protocols generate energy demands that exceed national supply in several cases (144% of daily demand for Senegal; 65% for Nigeria; 40% for South Africa; 80% for Kenya; 90% for Ghana). Although these magnitudes depend on parametric assumptions, they consistently indicate that large-scale PoW adoption is incompatible with existing power systems and therefore unsustainable without major transformations of energy infrastructure and operational models.
By contrast, Proof of Stake (PoS) protocols reduce energy exposure by orders of magnitude (benchmark reduction = 99.95%), offering a technically credible pathway to reconcile blockchain innovation with

sustainability objectives. Yet protocol substitution alone is insufficient. A responsible transition requires an integrated strategy combining regulatory clarity (harmonized legal and supervisory frameworks for crypto-assets and market infrastructure), technological support (promotion of energy-efficient architectures, sovereign permissioned chains and renewable-powered deployments), and economic and geopolitical measures (capacity building, technology transfer and regional partnerships to strengthen digital sovereignty). The pan-African comparison underscores that blockchain sustainability is a continent-wide policy challenge that calls for coordinated governance. More vulnerable countries would benefit from strategic partnerships with more resilient economies to pool expertise, financing and adaptive capacity. To capture blockchain's potential for financial inclusion without compromising energy resilience or economic sovereignty, African policymakers should prioritize energy-efficient protocol choices, regulatory harmonization and targeted regional cooperation. Such a coordinated approach offers the most credible path for Africa to harness blockchain benefits while preserving its energy security and long-term development objectives.

6. Declaration

The author declares that there is no conflict of interest regarding the publication of this manuscript. The research was conducted independently, without any financial or personal relationships that could inappropriately influence or bias the work. No external funding was received, and no commercial or institutional interests are involved in the results or conclusions presented.

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