Centralization and Decentralization of Digital Currencies: A Comparative Analysis of CBDC, Bitcoin and Ether

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ABSTRACT

The evolution of the global digital financial system is generating two main forms of digital currencies: a centralized currency system, such as Central Bank Digital Currency (CBDC), and a decentralized cryptocurrency system, like Bitcoin and Ether. This study aims to analyze the conceptual differences between the centralized (CBDC) and decentralized (Bitcoin and Ether) models and each operating mechanism. The study also examines how both models impact the stability of the economy and adherence to Shariah principles. Using the qualitative approach and exploratory design, the study examines materials on CBDC, Bitcoin, and Ether. The study collects data from central bank reports, monetary policy documents, academic articles, and technical papers published by relevant institutions. The content analysis method should identify similarities and differences between the currencies in terms of system architecture, infrastructure, technological efficiency, energy, governance and compatibility with Shariah principles. According to the study, CBDC, Bitcoin and Ether represent three distinct paradigms: Bitcoin's decentralized system, through proof-of-work, produces rather limited functionality to emphasise individual freedom and privacy, while Ether innovates the system via a switch to proof-of-stake and smart contracts, which leads to greater functionality. CBDC, on the other hand, maintains a centralized system to ensure monetary stability, but with a compromise on users' privacy. Hence, while maintaining the value of blockchain transparency and traceability without sacrificing economic stability, the study proposes a hybrid approach in order to improve transaction efficiency. The study suggests implementing a regulatory sandbox involving authorities, economists and Shariah experts as an initial test measure of this innovation to ensure security for users and compliance with the principles of Shariah in the development of a healthier digital financial ecosystem.

Keywords: CBDC, Bitcoin, Ether, DeFi, Blockchain, Smart Contracts

INTRODUCTION

Advances in digital technology have sparked a revolution in the global financial system through the emergence of digital currencies in the form of centralized Central Bank Digital Currency (CBDC) and decentralized (cryptocurrencies and DeFi). This innovation has challenged the conventional concept of finance based on intermediary institutions and demanded a reconstruction of the framework of understanding the function and regulation of money in the modern economy (Bech & Garratt, 2017; Treiblmaier, 2018). The Bank for International Settlements (BIS, 2024) study found that 91% of the world's 93 central banks are exploring CBDC development in response to declining cash use and increased asset tokenization, as well as concerns over the influence of private cryptocurrencies. These developments have not only brought technical changes but also changed the structure and fundamentals of the global financial system. Thus, any form of excessive control or absolute supervision by centralized institutions of digital currencies has the potential to contradict Shariah standards and have an impact on the economy and society (Anwer, Z. et al., 2020).

However, despite numerous studies on the economic and technical aspects of digital currencies (Kumhof & Noone, 2018; Adrian & Mancini-Griffoli, 2019; Allen, Gu & Jagtiani, 2022; Bech & Garratt, 2017; Waller,

2024), in-depth research into the question of the suitability and social impact of centralization and decentralization structures exemplified by CBDCs, Bitcoin, and Ether from a Shariah and social perspective is still limited. Most previous studies have focused more on the efficiency of the system, monetary stability, and economic policy implications without assessing the impact on freedom of ownership, conformity, and social justice, as well as Shariah validity (Anwer, Z. et al., 2020; El-Gari et al., 2022).

This gap demands an interdisciplinary analysis that combines the approach of Islamic financial philosophy and current financial technology innovations to formulate the principle of balance between maṣlahah and control (Rahman, 2024; Treiblmaier, 2018). The objective of this study is to re-evaluate the conceptual and operational aspects of Central Bank Digital Currency (CBDC), Bitcoin and Ether to unravel the social, economic and Shariah implications in the formation of a contemporary Islamic digital financial system.

LITERATURE HIGHLIGHTS

Centralization and Pre-Decentralization of the Financial System

The global financial system is dominated by a centralized structure, which is the focus of a single domestic and international central entity. This model allows central authorities to control the production of money, price stability, and the implementation of national monetary policies (Neuberger, 1959; Bech & Garratt, 2017). The fact that the system places assets at specific centralized institutions, this could imbalance power and wealth, typically because risks are borne collectively by all users (Rejeb, A. et al., 2021). Therefore, the reliance on central banks as "lenders of last resort" failed to curb systemic failures which took place during the global financial crisis in 2008 (Acharya et al., 2013; Stiglitz, 2010).

This failure later gave birth to an idea of decentralized finance (DeFi) system based on blockchain technology. In 2008, under the pseudonym Satoshi Nakamoto, Bitcoin was introduced as an alternative to the conventional financial system through the Bitcoin white paper: A Peer-to-Peer Electronic Cash System (Nakamoto, 2008).

Blockchain technology provides transparency, immutability, and high security, as each transaction is verified through cryptographic consensus by the network's participants (Treiblmaier, 2018; Wamba & Queiroz, 2020). These features are definitely an answer to the problem of "double spending", which is often the main challenge of conventional electronic systems (Nabilou, 2019; Rejeb, Keogh, & Treiblmaier, 2020).

Nevertheless, developments keep posing challenges to central bank functions, especially in controlling money supply and monetary stability. With the existence of digital currencies that are independent of state control, the role of central banks is seen to be diminishing (Kunaratskul et al., 2024). The study explains that the emergence of the Central Bank Digital Currency (CBDC) is a direct response to the threat of decentralization, particularly in the context of balance sheet stability and fiscal policy (IMF, 2024). Bank for International Settlements & Committee on Payments and Market Infrastructures (2024) combines the innovative functionality of tokenization (speed, automation) with the time-tested principles of central bank trust and control to ensure the "singleness of money" and financial stability, which may be challenged by fully decentralized systems.

Centralization in the Financial System

CBDC Architecture and Infrastructure

According to economists, CBDCs can be designed in several architectures (Kumhof & Noone, 2018; Adrian & Mancini-Griffoli, 2019; Bank for International Settlements [BIS], 2024):

1. **Indirect model –** users interact through intermediary banks that hold CBDC accounts in aggregate at central banks, while individual account management is handled by commercial financial institutions (Kumhof & Noone, 2018). This architecture maintains the traditional role of commercial banks and reduces the operational burden of central banks.
2. **Direct model –** puts all user accounts under the direct control of the central bank, which is responsible

for storing, recording and updating transactions in real time. While offering a high level of security and transparency, this model demands large-scale technological and infrastructure capabilities to accommodate the high volume of retail transactions.

3. **Hybrid model –** combines both approaches. Central banks retain final responsibility for consumers' financial claims, yet the day-to-day operations and verification of transactions are managed by intermediary banks (Adrian & Mancini-Griffoli, 2019; Baudino et al., 2019; Bindseil & Senner, 2024). This model is more attractive because it offers a balance between central control, transparency, and operational efficiency and is considered the most viable for global implementation in the long term (IMF, 2024; BIS, 2024).

CBDC infrastructure design can use centralized conventional databases or distributed ledger technology (DLT). Centralized systems offer high speed but are vulnerable to single-point attacks; on the contrary, DLT requires consensus but increases resiliency. The BIS study shows many countries are weighing the need for tokenization and the effectiveness of programmability in CBDCs.

Access and Cross-Border Function

Retail CBDCs can essentially be designed in two main forms, either account-based or token-based. Account-based CBDCs allow users to be accessed through digital identity systems such as electronic bank accounts, which facilitates the implementation of Know Your Customer (KYC) and Anti-Money Laundering (AML) mechanisms but reduces the level of privacy of users (IMF, 2024). On the other hand, token-based CBDCs offer a higher level of direct transfer (peer-to-peer) and privacy but face the risk of losing digital keys as well as the risk of verifying the identity of foreign users (BIS, 2024).

In a cross-border context, CBDCs are seen as capable of transforming the landscape of the international payment system through reduced remittance costs, increased transaction speeds, and improved efficiency of foreign exchange (FX) settlements, in line with the global goal of making the financial system more inclusive and interoperable (IMF, 2024; Illes, A., 2025). Based on The Bank for International Settlements report (2025), the high market demand for cheaper and faster cross-border payment systems is signaled by a more widespread use of stablecoins for cross-border payments in developing countries than in domestic transactions.

However, the risks of stability and transparency of backing assets in stablecoins are warned by the BIS, thus calling for the development of cross-border CBDCs. The call is to initiate compliance frameworks and interoperable technical standards between central banks. Overall, CBDC's potential to become a secure, inexpensive, and efficient alternative to international remittances depends on the balance between privacy, compliance, and interbank cooperation in shaping a more stable and inclusive global monetary ecosystem (World Bank, 2024; Illes, A., 2025).

Decentralized System and Blockchain

Distributed Ledger Technology (DLT) refers to a shared system of digital records that are maintained collectively across multiple entities within a network, removing the need for a central intermediary. It serves as the key foundation that allows decentralized systems to function. In practice, each participant or “node” keeps an identical copy of the ledger and validates new transactions through consensus mechanisms such as proof-of-work (PoW) or proof-of-stake (PoS) (Xu et al., 2020; Conti et al., 2019). As noted by Markus et al. (2019) and Rejeb and Treiblmaier (2024), these mechanisms are designed to create trust using cryptographic tools and collective verification rather than a single institutional authority.

In terms of structure, DLT can be divided into two main forms: public ledgers like Bitcoin and Ethereum that feature total openness, allowing all users to access and verify transactions without restrictions. This feature provides a high level of transparency and a resistance to manipulations and permissioned ledgers (Markus et al., 2019; Bakos & Halaburda, 2022; BIS, 2024). (Rejeb, Rejeb, & Keogh, 2021; Hassan, 2025). On the other hand, permissioned ledgers limit access to only certain entities with different levels of permission. This model is more efficient and secure, making it popular in the financial sector (Bakos & Halaburda, 2022; Rejeb & Treiblmaier, 2024).

Decentralized ledgers operate on a peer-to-peer basis, which allows all nodes to be directly involved in authentication and data storage (Iansiti & Lakhani, 2017; Saad et al., 2021). This structure will eliminate single points of failure and enhance the system's resilience to data manipulation or cyberattacks (Wamba & Queiroz, 2020), unlike conventional ledgers that rely only on a single entity to record and verify transactions.

According to recent studies, blockchain is the foundation of the new digital economy architecture by combining cryptographic technology and game theory with communication networks (Narula, 2025; Commey & Nkenyereye, 2024). This architecture inarguably builds trust through transparency, traceability, and immutability of every verified transaction. As such, blockchain technology is widely adopted for current and future digital innovation in finance, health, law, and supply chains (Treiblmaier et al., 2020; Duan et al., 2020).

Overall, the research finds out that there is no single model that appears to be absolutely superior, as both systems provide their own unique advantages. A centralized ledger contributes better stability, control, and regulatory compliance, which is suitable for national systems. However, a distributed ledger technology is more transparent and trusted, which suits open ecosystems such as FinTech and DeFi. Hence, hybrid approaches that combine institutional control with the advantages of decentralized technologies, such as permissioned blockchain models (e.g., Dragonchain and Kadena), are increasingly adopted as a middle ground (IMF, 2024; Bank for International Settlements & Committee on Payments and Market Infrastructures, 2024).

3.1Bitcoin and Proof-of-Work (PoW) algorithms

Bitcoin mining is a specific process aimed at creating new Bitcoin units and processing all transactions involved. Bitcoin was designed by its creators with a limit that can only reach 21 million Bitcoins (21 million BTC). The Bitcoin units can be broken down into smaller units called Satoshi. 1 Bitcoin is equivalent to 100,000,000 Satoshi (Nakamoto, 2008; Antonopoulos, 2017). Proof-of-Work (PoW) is the only mechanism used to generate Bitcoin units, in which miners will use software found on specific computer hardware to solve complex cryptographic puzzles and later add new blocks to the blockchain ledger, then be rewarded with new Bitcoins in return to the miner who has generated and utilized high computing power to maintain Bitcoin. It is a process that Bitcoin usually consume concerning high energy every year (Nian & Lee, 2015).

The withdrawal rate of a new Bitcoin is determined by a protocol designed to adjust the mining difficulty level so that a new block appears every about ten minutes, making its supply limited and its inflation controlled (Nian & Lee, 2015; Tindell, 2013).

Technically, the fact that mining activities now tend to be operated by large-scale mining pools in areas of cheap energy and even raise issues of computational power density, environmental impact, and decentralization imbalance, the phenomenon caused by mining operations that implement an intensive mathematical process using energy and high-powered hardware to solve the SHA-256 hash function (BIS, 2024; Cong et al., 2020). The Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024) and ByteTree Research (2024) reported that the Bitcoin network is estimated to consume about 150 terawatt-hours (TWh) of electricity every year, which equals the annual energy consumption of a medium-sized country like Malaysia or Argentina. The UNCTAD Digital Economy Report (2024) study also reported the consumption of around 120 TWh in 2023, making Bitcoin one of the most energy-intensive payment systems in the world.

Ether, Proof-of-Stake (PoS) and Smart Contracts

Ether (ETH) is a digital currency that serves as a medium of exchange, an investment tool, and a store of value in the blockchain technology ecosystem of Ethereum, an open-source blockchain network that supports the development of decentralized applications (dApps) and smart contracts. This network is the basis for transactions and the use of Ether as a primary digital asset (Buterin, 2015; Xu et al., 2021). According to Avital (2021), Ethereum allows for the movement of funds that is not only simple but also supports various forms of complex transactions, including asset exchanges and digital loans based on fractional ownership.

To enable any interaction within the Ethereum application—whether it is changing, creating, or deleting any digital note—users will need to pay a fee in Ether. This cost varies depending on the level of computational

power required to complete the task. (Michael, 2019; Richard, 2017).

Between 2014 and 2022, the consensus mechanism of Ethereum used was the Proof-of-Work (PoW). Later in 2023, the Merge update transitioned the mechanism from PoW to Proof-of-Stake (PoS), a form of distributed consensus used by blockchain networks to reach agreement on the authenticity of transaction data. The Proof-of-Work (PoW) mechanism will demand high use of processing power through mining activities, which is different compared to the PoS mechanism that stipulates that validators make a certain amount of digital assets – in the case of Ethereum, it is Ether (ETH) – as collateral as a stake to participate in the block verification process (Solomon, 2019).

Technically, a smart contract is a type of account in Ethereum that stores balances and executes commands according to a pre-programmed code script. It cannot be deleted, and its implementation is automatic and cannot be cancelled (Grincalaitis, 2019). In this system, the staked Ether is included in a smart contract and acts as a guarantee of trust in the honest behavior of the validator. If the validator fails to fulfil his or her responsibilities, such as not participating when summoned, or committing integrity violations such as proposing more than one block in a slot, or making conflicting attestations, then the Ether collateral will be penalized and may even be eliminated (Brian et al., 2019; Solomon, 2019). The system creates economic incentives for honest behavior and penalties against abuse, making PoS safer, more efficient, and ethical from an energy sustainability standpoint than PoW (Ethereum Foundation, 2025; BlockApps, 2024).

Privacy and Pseudonymity

Technically, most systems such as Bitcoin and Ethereum are not completely anonymous, instead operating in a pseudonymous form, i.e., the user's identity is hidden behind a public address in the form of strings of letters and numbers (Brito & Castillo, 2013; Ethereum Foundation, 2025). The fact that no real name is recorded, but identity analysis can still be identified. This is because every transaction is stored permanently in a public ledger along with information such as the public key, transaction amount, and timestamp, making.

Androulaki et al. (2013) found that over 40% of Bitcoin users can be identified through transaction behavior analysis using methods such as graph analysis and entity clustering. Reid and Harrigan (2013) and Ober et al. (2013) also discovered that the use of more than one address never guarantees confidentiality and can possibly be compromised. The Ethereum users have wallets like MetaMask or MyEtherWallet that will log all transactions on blockchains that are open to the public, potentially making every interaction with dApps and regulatory exchanges compromise user privacy.

In recent years, international regulators have tightened regulation policies such as the Travel Rule by the Financial Action Task Force (FATF, 2023) and the Markets in Crypto-Assets Regulation (MiCA) by the European Union (EU, 2023), aiming at transparency aspects of crypto transactions, which requires crypto service providers to report the identity of senders and recipients for transactions above certain thresholds. These policies will prevent finance that involves money laundering and terrorism activity (Biryukov et al., 2014; FATF, 2023). This phenomenon will soon spark arguments and debates among users and developers to fight between transparency requirements and digital privacy rights, two fundamental principles that often contradict in decentralized finance (DeFi) frameworks.

Decentralized Finance (DeFi) Ecosystem

Decentralized Finance (DeFi) is a new and revolutionary financial system that eliminates all aspects of intermediaries and promotes full data openness, permissionlessness, tokenization of assets, self-ownership, community governance, scalability, cross-border togetherness, and, most importantly, the essence of the execution of smart contracts that enable the system to exist and operate. This technological financial system marked a significant shift that became a great challenge to conventional system industry players (Schär, 2021; Allen et al., 2023; Werner et al., 2023; Harvey et al., 2021; Zetzsche et al., 2022; Ethereum Foundation, 2025).

Decentralized finance marked a significant position in the era of the modern financial system. While Ether functions as the main token and source of life in the Ethereum network, which serves as an underlying

infrastructure for multiple DeFi applications and protocols, Bitcoin, on the other hand, is fully decentralized in nature and not designed for DeFi, but it can be tokenized and made as digital collateral that fits perfectly the DeFi application, such as Wrapped Bitcoin or WBTC (Antonopoulos, 2017). This made DeFi a middle spectrum between a decentralized Bitcoin and Ether and a fully digital centralized like CBDC, which is designed to pave a new path towards a greater field of digital financial systems in the future.

Central Bank Digital Currency (CBDC), on the other hand, maintains a centralized control structure by central banks while leveraging blockchain technology. Its main goal is to ensure monetary stability and the implementation of national economic policies, while mimicking the transparency and efficiency aspects of transactions found in DeFi technologies, but in a more regulated and law-abiding framework (BIS, 2023; IMF, 2024).

METHODOLOGY

This study used a qualitative approach with the design of the exploratory study. Data was collected through documentation methods by referring to classical and contemporary fiqah scholars, as well as reading materials related to digital currencies in the context of CBDC, Bitcoin and Ether, from the aspects of system architecture, infrastructure, technological efficiency, energy sustainability and governance, as well as compatibility with Shariah principles. The data was analyzed using content analysis and thematic analysis methods to obtain key issues and themes related to social and economic implications, as well as the validity of Shariah.

FINDINGS

Comparative Analysis of CBDC, Bitcoin and Ether

The comparative analysis between Bitcoin, Ether and CBDC was conducted based on four main aspects, namely structure, control, technology and scalability, to see the differences in philosophy and objectives of their respective digital financial systems.

In terms of structure, Bitcoin is developed based on a peer-to-peer network that is fully decentralized in nature without any central control entity (Nakamoto, 2008; Antonopoulos, 2017). While Ether makes no difference in terms of the openness feature, it takes cryptocurrencies an extensive mile by enabling smart contract functionality. This upgrade makes automatic execution of transactions based on custom code and logic a key contribution to the emergence of DeFi (King & Nadal, 2012; BlockApps, 2023). On the other hand, CBDCs are consistent with traditional finance philosophy; they are structured in a centralized manner, which makes the central bank the sole issuer and supervisor to ensure monetary stability and compliance with the country's fiscal policies (BIS, 2023; IMF, 2024).

In terms of control, the consensus of the community of many users and developers will collectively govern and manage Bitcoin or Ether, which is in line with principles of openness and network governance. In contrast with Bitcoin and Ether, CBDCs are fully controlled and supervised by central banks, consistent with the conventional financial instrument spirit, which aims at keeping the monetary authority to strengthen the integrity of the country's financial system (BIS, 2023).

From a technological point of view, the PoW algorithm that emphasizes network transparency and security is used by Bitcoin. Ether, on the other hand, made a technological upgrade by shifting from the PoW algorithm to PoS, which records improved energy efficiency and better transaction processing capacity (BlockApps, 2023). CBDCs, on the other hand, operate through centralized databases and limited-scale distributed ledger (DLT) technologies, with an emphasis on institutional reliability and systemic stability (BIS, 2023).

Finally, in terms of scalability, Bitcoin processing capability is limited to around seven transactions per second, while Ether has more enhanced capability, which can process around 30 to 100 transactions per second after shifting from PoW to PoS. On the other hand, CBDCs are designed to support large-scale transactions with fast processing rates, on par with existing central banking systems (IMF, 2024).

In general, this analysis finds out that Bitcoin and Ether's technological innovation sparks an unprecedented and unorthodox financial system in the era of the modern digital world by representing a fully open and decentralized financial system, while centralized CBDCs approach remains focused on stability, control, and compliance with national monetary policies. These differences can be summarized as shown in Table 1, which details the comparison of each of the main aspects.

Table 1: Summary of the Comparison Between CBDC, Bitcoin, and Ether

Aspects	Bitcoin	Ether (Ethereum)	CBDC
Creator/Entity	individual/pseudonym (Satoshi Nakamoto)	Vitalik Buterin & Ethereum Foundation	The country's central bank
Launch year	2009	2015	Depends on the country (example: China started e-CNY testing in 2020)
System properties	Full decentralization	Decentralization with smart contract functionality	Centralized
Ledger type	Public and without permission	Public and without permission	Private; Controlled by the government
Algorithm consensus	Proof-of-Work	Proof-of-Stake	None (depending on centralized database)
Control/authority	Open community	Ethereum Community & Foundation	Central bank
Scalability	±7 transactions/moment (PoW)	±30–100 transactions/moment (PoS)	High (based on the central bank system)
User privacy	Pseudonymous but traceable	Pseudonymous but traceable	Limited; Identity required
Transaction fees	Have, depending on network congestion	Have, changes according to "gas"	Low or no
Smart contract support	Limited (via secondary protocols)	Fully supported	Depends on the design

Based on the comparison in Table 1, Bitcoin has the most basic decentralized function features: a managerless digital value system using the proof-of-work (PoW) consensus mechanism, limited scalability, and unfitness for smart contracts. While Ether via the Ethereum network has exceeded Bitcoin by supporting smart contracts and DeFi applications, as well as switching to proof-of-stake (PoS), which improved energy efficiency and transaction capacity. This distinct difference shows two different spectrums of Bitcoin and Ether. CBDC, on the other hand, despite using blockchain elements, is on the opposite end of the spectrum, maintaining centralized control by central banks and is designed to achieve monetary stability and legal compliance, but at the expense of a level of decentralization and user privacy. Hence, it can be concluded that these three currency systems represent three different spectrums in the evolution of the digital financial system.

Overall, the Bitcoin spectrum emphasizes basic individual freedom and decentralized autonomy, while the Ethereum spectrum focuses on DeFi innovation and sparks future unprecedented financial technology, while CBDCs highlight stability and centralized surveillance as the foundation of the modern national digital monetary system.

DISCUSSION

Social, Economic and Shariah Implications

Financial Inclusion and Social Development

Based on Table 1, comparisons between CBDCs, Bitcoin, and Ether of Ethereum, the three spectrums of currency systems, show different implications for financial inclusion and social development. CBDCs have the potential to expand financial access to the unbanked through official digital wallets, improve the efficiency of the distribution of social assistance, zakat and subsidies, and support the country's economic stability. However, its centrally regulated nature raises concerns for individual privacy and financial freedom (BIS, 2023; IMF, 2024).

Unlike CBDCs, Bitcoin offers global transaction freedom with the elimination of intermediaries in transactions, such a useful instrument for those living in a weak financial system (Nakamoto, 2008; Antonopoulos, 2017). Nevertheless, it is unsuitable for long-term social development due to extreme volatility, high fees, and lack of regulation.

On the other hand, Ether in its Ethereum network enables open access to loans, investments, and digital transactions without financial institutions via its innovative DeFi system, thus strengthening the cooperative economy and digital inclusion (Younes, 2022; World Economic Forum, 2021). However, the risk of usury and speculation requires legal guidance and control of Islamic ethics (El Amri et al., 2019; Hassan et al., 2025; Jahangir et al., 2025).

In summary, given the fact that CBDCs remain the centralized structure that tends to be widely supervised and discussed by many economists and Shariah experts, CBDCs will be more suitable for structured and Shariah-compliant social development, while Bitcoin symbolizes individual financial freedom but is unstable and tends to be a more speculation-driven form of profits. On the other hand, the flexibility of Ether that enables DeFi promotes inclusive innovations and welcomes Shariah discussion among experts and may possibly reach the integration of the principles of Maqāṣid Shariah to feature economic justice and social welfare.

Energy and Environmental Security

The mining process mechanism of proof-of-work (PoW) that is used in the Bitcoin network marked a significant increase in demand for extreme utilization of energy globally and sparked global carbon emission concerns. The situation is due to an extensive computing programme that takes place during the verification of transactions and new bitcoin unit creation. The network is reported to consume over 121 TWh a year (Cambridge Centre for Alternative Finance, 2024). Meanwhile, the energy consumed by the Ethereum network is reported to be only about 0.0026 TWh after the mechanism is fully transitioned in 2023 from proof-of-work to proof-of-stake, which consumed about 78 TWh before the transition, marking a significant decrease of 99.95% (Ethereum Foundation, 2024). Further study by de Vries et al. (2023) estimated Bitcoin's carbon footprint to reach 68.4 million tonnes of CO_2 per year, while Ethereum is now close to reaching the level of zero carbon emissions.

The mining situation implicated energy security significantly, as the PoW model poses a risk to the local overloaded energy grid. Furthermore, this high energy-consuming model would potentially cause an increase in electricity prices that is borne by every consumer, miner and non-miner collectively due to an inelastic demand for bitcoin mining (Gallersdörfer, Klaaßen & Stoll, 2020). In comparison with the Ethereum PoS mechanism, which resolved this issue with its brilliant transition, it thus makes it a more suitable and sustainable alternative to the future digital financial system.

From a security standpoint, PoW maintains integrity through "security through work"—it takes 51% of computing power to attack—but at a high energy cost. PoS, on the other hand, operates on the principle of "security through stake", where miners stake their own assets during validating transactions. An attack on the network will affect the value of the perpetrator's holdings, thus maintaining internal incentives for system

security (Buterin, 2022).

Overall, Ethereum's shift to proof-of-stake ignites a brilliant evolution in blockchain technology and decentralized finance. It proves that security of the Ethereum network and environmental sustainability are not two conflicting goals. In the context of global decentralization, the increasing urgency towards carbon reduction, PoS is not just an option but a necessity to ensure a greener and more resilient blockchain future. In the context of the world's move toward decentralized finance, an environmental policy should promote and even incentivize the innovation that utilizes low-energy consensus mechanisms and renewable resources. Digital finance that adopts green infrastructure will set an example across the industries in shifting to low-carbon mass-production processes.

Shariah Validity

In the context of Islamic law, a world that cannot run away from innovation must always be in line with the principles of Sharia law. All human activities and desires must be centered on the Quran and Sunnah because all the answers are in it, as Allah SWT says: 'We have not neglected the book' (The Quran, 6:38). This includes the world of digital currencies, which must be away from banned elements such as gharar, usury and gambling. In the context of CBDCs, it must be consistent with the Maqāsid Shariah, which emphasizes the principles of trust and fairness, which means the data of each of its users must be kept from being exposed to misuse by financial institutions or the government. User data should be protected as best as possible and only used for the right purposes, such as combating corruption and money laundering. (al-Qaradawi, 1995; al-Qaradaghi, 2022). Contemporary scholars such as El-Gari (2022) and Abu Ghuddah (2021) insist that financial innovations such as CBDCs must maintain a balance between general maṣlahah and ḥifẓ al-māl, as well as not lead to oppressive forms of surveillance.

From the Islamic economic dimension, the implementation of CBDC can improve the efficiency of the payment system, fiscal transparency, and monetary resilience of the country (Auer et al., 2020; Al-Mashaqbeh, 2024). CBDCs also have the potential to strengthen price stability and fairness in the distribution of wealth through reducing transaction costs and reliance on usury-based commercial banking systems (Anwer, Z. et al., 2020). However, if their implementation is not accompanied by good Shariah controls, CBDCs can widen the economic inequality gap and increase the risk of exploiting user data for political or commercial purposes.

On the other hand, Bitcoin and Ether require in-depth scrutiny of their value volatility and use as a speculation tool, as well as the integration of their smart contracts that may contain gharar elements in the form of yield volatility or automated transaction risk. While blockchain technology provides information fairness and transparency, it also opens space for imbalances in access and exploitation of digital capital by certain parties.

In this context, Islamic law emphasizes the concept of fiqh tawāzun, which integrates digital innovation and social responsibility with the Shariah law. The development of a digital system that is in line with the stipulation of Shariah must be formed and even become the basic value behind the Bitcoin, Ether and CBDC innovations for the sake of universal justice, which is the main focal point in the general concept of maṣlaḥah. Thus, these systems play their role in empowering the real economy of Muslims and are not just a speculative profit-generating tool. (El-Gari, 2022; Jam‘an, A. et al., 2024; Chapra, 2008).

The synergy that features strategic collaboration between academicians, authoritative bodies, Shariah experts and technologists must be systematically initiated where every party will contribute an active role, representing issues and solutions in producing a comprehensive understanding and knowledge that crosses fields. Strategic collaboration will generate a balanced ecosystem that embraces Shariah and the reality of the digital financial system, which will promote justice and prosperity for all societies. (Abdullah & Oseni, 2021; Al-Qaradaghi, 2022).

CONCLUSIONS AND RECOMMENDATIONS

In the global financial landscape, the innovation of digital currencies is such a significant paradigm shift. Central Bank Digital Currency (CBDC), which represents a centralized digital conventional system, features

great stability, efficient monetary policy execution and extensive adaptability with current banking systems. However, the system also raises privacy concerns and autonomy aspects of users, which is the main reason for the emergence of decentralized financial system.

Although the decentralized network system, such as Bitcoin and Ether, features an excellent spirit of innovation and transparency, as well as individual freedom in financial transactions, it still faces obstacles of value instability, speculative risk, and constraints in terms of a fully immature regulatory framework (Baur et al., 2018).

The emergence of Decentralized Finance (DeFi) proves that the financial system can operate without dependence on intermediaries, in line with the principles of decentralization that are at the core of blockchain technology. However, the long-term success of DeFi depends on the robustness of digital infrastructure and governance efficiency, as well as a mature level of consumer financial literacy — factors that increasingly show positive developments in line with the increasing number of users and the continued advancement of technology (Schär, 2021; Gudgeon et al., 2022).

Therefore, the future of digital finance requires a hybrid approach that combines the efficiency and stability of CBDCs with blockchain technology innovations that would emphasize the cryptographic security, transparency, programmability, as well as resilience of the DLT. In fact, the idea of a hybrid concept is presently piloted in many countries, like e-CNY in China, Project Jasper in Canada, Project Ubin in Singapore, and the Digital Euro Project by the European Central Bank, as well as Project mBridge by BIS Innovation Hub, which is an inter-central bank collaboration between the Hong Kong Monetary Authority, the Bank of Thailand, the Digital Currency Institute of the People's Bank of China and the Central Bank of the United Arab Emirates. This initiative is currently beyond a theoretical concept and is instead a dominant design approach implemented by multiple central banks worldwide (Auer et al., 2022; BIS, 2020; BIS, 2022; PBC, 2021; BIS, 2023; ECB, 2022). This approach is not only a technical development but also ethical and Shariah, which ensures that the financial system is in accordance with Maqasid Syariah to uphold justice, reject harm, and preserve the wealth and welfare of the people while embracing technological innovation.

The hybrid approach could enable an elimination of riba and gharar in adhering to the strict and basic Islamic jurisprudence principles (Khairuddin et al., 2025). The experts could explicitly design the CBDCs to be the non-interest-bearing currency. Thanks to the flexibility of smart contracts on blockchain, it also enables better transparent governance while minimizing the influence of gharar in transactions. Plus, the innovation could also welcome management of zakat and waqf funds (Pati & Sultan, 2023; Prayudya & Al-Ayubi, 2023). These innovation advantages are definitely in line with the preserves of Maqasid of Shariah, especially the hifz māl, and promote a just economic and social life of the ummah.

However, the disagreement between scholars in views and fatwas regarding digital currencies is undeniably the ongoing challenge. Therefore, the cooperation of each party and the implementation of a regulatory sandbox regulated by Shariah experts at domestic and international levels are very necessary to ensure that every digital financial innovation is tested from the point of view of Shariah and legal compliance before being widely applied. This approach can strengthen the ruling of fatwas and ensure harmony between Shariah principles and the use of digital currency technology among Muslims today and in the future (Muneeza & Nurhayati, 2020; Islamic Financial Services Board [IFSB], 2022).

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