World Bank Group Korea Office
Innovation and Technology Note Series

JULY 2022, NOTE SERIES NUMBER 8

Environmental Implications of a Central Bank Digital Currency (CBDC)

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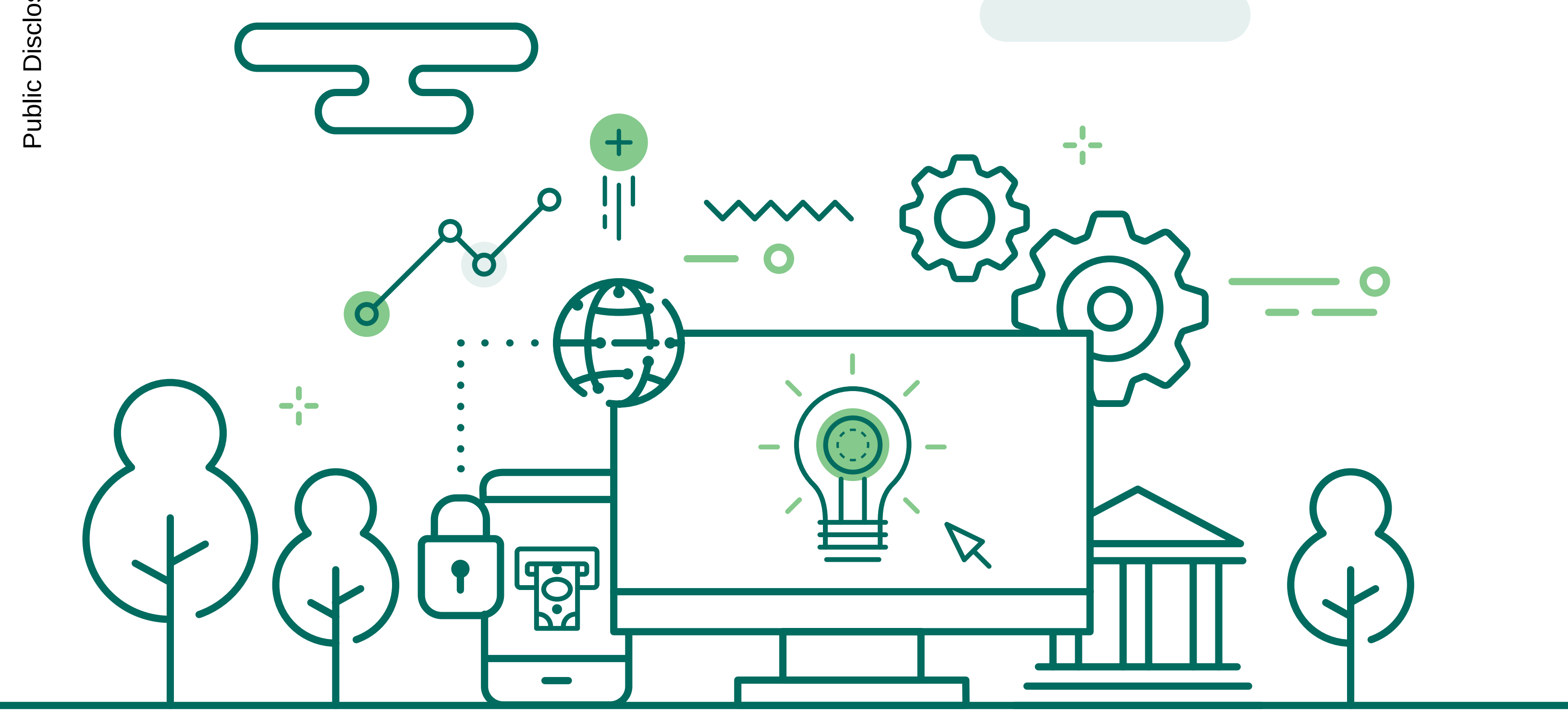

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Abstract

Two-thirds of central banks in the East Asia and Pacific (EAP) region have started researching or testing the implementation of a Central Bank Digital Currency (CBDC). At the same time, the region accounts for one-third of world CO2 emissions and is vulnerable to climate risks. As the Group of 7 (G7), European Central Bank (ECB), and Bank of England (BoE) have stated in their public statements, it is increasingly important to consider environmental impact when designing CBDC. However, only a few brief studies have been done on this subject, which will be crucial for the region. This Note explores the environmental implications of CBDC by comparing technical mechanisms and energy consumption within its distributed structure. It also illustrates differences in ecological footprint between CBDC and other payment methods (cryptocurrency, cash, and card networks). As the legitimacy of CBDC is backed by the trust of central banks, CBDC does not need to prove its legitimacy through its technological structure. Therefore, CBDC does not require the energy-intensive consensus or mining mechanisms used by a cryptocurrency, so its energy consumption is lower (comparable to that of a credit card system). CBDC can be designed to use various systems, such as Real Time Gross Settlement (RTGS), Distributed Ledger Technology (DLT), or a mixture of both. Careful deliberation to meet the objectives and implications will be important as CBDC can be a catalyst for financial innovation.

Acknowledgements

This Note is a product of the East Asia and Pacific Region, Financial, Competitiveness and Innovation Practice, Seoul Center for Finance and Innovation, and the Information, Technology and Solutions Vice Presidency, of the World Bank Group. It is part of a larger effort by the World Bank Korea Office to focus on technology and innovation issues and contribute to development policy discussions around technology and innovation matters in East Asia and the Pacific and beyond. This Note's findings, interpretations and conclusions are entirely those of the authors and do not necessarily represent the views of the World Bank Group, their Executive Directors, or the countries they represent.

The authors appreciate guidance and comments from Zafer Mustafaoglu (Practice Manager, FCI EAP1), Stela Mocan (Manager, ITSTI), Stuart Yikona (Program Manager, FCI Seoul Center), Ahmed Faragallah (Senior Financial Sector Specialist, EFNFI), Erik Feyen (Lead Financial Sector Economist, EFNDR), Rachel Halsema (IT Officer, ITSTI), Raunak Mittal (IT Officer, ITSTI), and Yongdae Kim (IT Officer, ITSTI). The authors also thank John Steinhardt for the editorial review. Loun Lee, Former IT Officer at ITSTI was a contributor on early drafts until Feb 2022. The authors may be contacted at slee55@worldbank.org, and jpark23@worldbankgroup.org.

Cover design/page design: Design Sol

The Korea Office Innovation and Technology Note Series is intended to summarize Korea's good practices and key policy findings on topics related to innovation and technology. They are produced by the Korea Office of the World Bank. The views expressed here are those of the authors and do not necessarily reflect those of the World Bank. The notes are available at: https://www.worldbank.org/en/country/korea.

Acronyms and Abbreviations

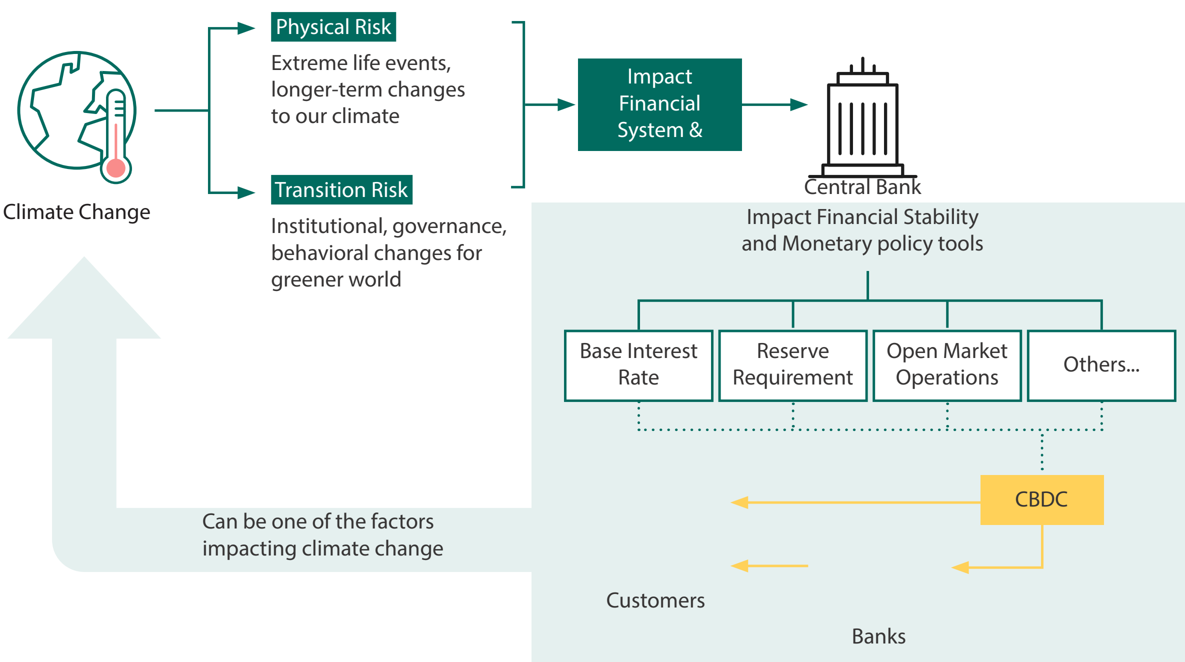
ATM	Automated Teller Machine
BIS	Bank for International Settlements
BoE	Bank of England
CBDC	Central Bank Digital Currency
DLT	Distributed Ledger Technology
DNB	De Nederlandsche Bank
ECB	European Central Bank
EAP	East Asia and Pacific
EUBOF	European Union Blockchain Observatory & Forum
FCI	Finance, Competitiveness & Innovation Global Practice
G7	Group of 7
GRID	Green, Resilient, and Inclusive Development
IMF	International Monetary Fund
ITSTI	Information & Technology Solutions Technology & Innovation Lab / Unit
kWh	Kilowatt hour
PBFT	Practical Byzantine Fault Tolerance
RTGS	Real-Time Gross Settlement
SAR	Special Administrative Region
SPOF	Single Point of Failure

I. Context Setting and Objective

Although there is a growing awareness of the need to consider the environmental implications of financial and monetary policies around the world, such discussions are hardly found in relation to Central Bank Digital Currency (CBDC), which has attracted many central banks' attention in recent years. CBDC is expected to bring about fundamental changes to monetary policy measures, hence most of the research on CBDC has focused on its impact on financial stability and payment systems. Since last year, public discussions on environmental considerations of CBDC seem to have started in earnest. As seen in Box 1, the Group of 7 (G7),[1] European Central Bank (ECB),[2] and Bank of England (BoE)[3] each announced principles or requirements in designing CBDC, and one of these was to consider ecological footprint. There have been some initial efforts to look at this principle closely.[4] However, research truly focused on environmental aspects is still in its infancy, because CBDC is a new area without precedent and only a few countries have fully implemented CBDC.[5]

If CBDC is adopted, environmental awareness of CBDC will be important because it will be related to the long-term sustainability of an economy. Climate change will affect monetary and financial stability in the long term through physical risks (such as extreme life events and long-term changes to the climate) and transition risks (that is, behavioral changes for a greener world).[6] The overall environmental impact will not be limited to the lives of individuals; rather, it will affect overall financial stability and monetary policy tools. CBDC can be used to serve as a monetary policy tool and a payment method: it is therefore vital to assess CBDC's potential impact on the environment in advance. This direct and indirect relationship between climate change and CBDC is illustrated in Figure 1.

Figure 1. Relationship between climate change and CBDC



Source: Author

1 G7, "Public Policy Principles for Retail Central Bank Digital Currencies," October 2021.
2 ECB, "Report on a digital euro," October 2020.
3 Bank of England, "The Bank of England's climate-related financial disclosure 2021," June 2021.
4 Giaglis et al. (2021) Proposed design options for the digital euro as well as considerations in technical, economic, and macroprudential aspects.
5 At the time of finalizing this Note, the IMF published a Fintech Note titled "Digital Currencies and Energy Consumption" on June 7, 2022. This IMF Note confirms that the energy consumption of crypto assets, as well as CBDC, is related to the technical design options supporting DLT network, and some of the design options can be less energy efficient than the current payment system. These observations are broadly in accordance with the conclusions of this Note.
6 Financial Stability Board, "The Implications of Climate Change for Financial Stability," November 2020.

Therefore, this Note aims to contribute to the exploration of CBDC and raise awareness of its environmental impact, especially for client countries in the East Asia and Pacific (EAP) region. According to Climate Watch, the EAP region is particularly vulnerable to climate change, accounting for one-third of world CO2 emissions.[7] The long-term Climate Risk Index, which analyzes the human and economic losses caused by extreme weather events between 2000 and 2019, shows that six countries from the EAP ranked among the world's most vulnerable 20 countries.[8] More frequent and severe natural disasters, the prevalence of tropical diseases, and poor air and water quality are all substantial risks to the region's growth and well-being. Meanwhile, as seen in Table 1, two-thirds of central banks in the EAP region have embarked on researching or testing the implementation of a CBDC. In this regard, it will be necessary to infer early lessons on the CBDC's ecological impacts for the EAP region, the better to respond to these expected risks proactively. This will be in line with the World Bank Group's Green, Resilient, and Inclusive Development (GRID) framework suggesting a balanced approach focused on development, inclusion, and sustainability in ways that are tailored to country development needs and objectives.[9]

Table 1. CBDC development stage in the EAP region (○ = retail, ● = wholesale)

None	Research		Proof of Concept		Pilot	
Mongolia	○	Australia	●○	Japan	○	China
Brunei	○	New Zealand	●	Thailand	●	Singapore
Myanmar	○	Thailand	●	Hong Kong SAR	○	South Korea
Timor-Leste	○	Hong Kong SAR				
Pacific Islands	○	Macao SAR				
Cambodia	●	Malaysia				
	○	Vietnam				
	○	Philippines				
	○	Lao PDR				
	○	Indonesia				

Source: Central banks website, CBDC Tracker, S&P Global Ratings. "The Future of Banking: Central Bank Digital Currencies in Asia-Pacific—Pathways Are Plenty, Destination is Uncertain." (2021)

This Note does not seek to generate or recommend policies; rather, it points out environmental factors to be understood when designing CBDCs. Similarly, this Note is not intended to create methodologies for assessing and evaluating the carbon footprint of payments systems, including CBDC (such an undertaking must be predicated on very extensive data and resources); rather, the Note uses existing research papers and data to examine and compare environmental opportunities presented by each payment system. We acknowledge our limitations; and further research will be needed when additional data becomes available.

7 World Resources Institute. Climate Watch Historical Country Greenhouse Gas Emissions Data (1990–2018).
8 David Eckstein, Vera Künzel, Laura Schäfer, "Global Climate Index 2021," Germanwatch Briefing Paper, January 2021.
9 World Bank Group, "Green, Resilient, and Inclusive Development," October 2021.

Box 1. CBDC Design Implications/Principles

The research and development of CBDC design principles are still at an early stage. However, governments and organizations are making efforts to address those issues. The G7 published the report "*Public Policy Principles for Retail Central Bank Digital Currencies*," outlining foundational principles to guide and inform the exploration and potential development of CBDC. It also addresses the environmental principle that energy usage should be factored into the design and implementation of any CBDC from the outset:

- Principle 8: The energy usage of any CBDC infrastructure should be as efficient as possible to support the international community's shared commitments to transition to a 'net zero' economy.

The report notes that CBDC can present the opportunity to set a marker for how future payment and settlement ecosystems are designed for optimal energy efficiency, including through the use of carbon-neutral and sustainable energy sources, while achieving necessary functional, performance, and resilience aims. Considering that processing, storing, and transferring information is becoming a significant user of global energy, CBDC can open up new possibilities for the energy and environment sector.[10]

Meanwhile, ECB published a report on a digital euro in October 2020 addressing several principles and requirements—accessibility, robustness, safety, efficiency, and privacy, while complying with relevant legislation. ECB emphasized that the Eurosystem will proactively support improvements in the monetary and payment system's overall costs and ecological footprint, achieving higher energy efficiency:

- Requirement 7b (R7b): Environmentally friendly. The design of the digital euro should be based on technological solutions that minimize its ecological footprint and improve that of the current payment ecosystem.[11]

The Bank of England (BoE) also claimed that any future decisions on CBDC issuance and design would consider the Bank's climate strategy and the recent changes in the remit of and recommendations to BoE policy committees.[12]

II. Hypothesis and Methodology

To identify the environmental impact of CBDC and assess potential related risks, this Note aims to address the intrinsic structure and characteristics of CBDC and its difference from other payment methods from the environmental perspective, as seen in Figure 2. It mainly focuses on two processes of the CBDC lifecycle, which are production and circulation. It seeks to provide critical interpretation based on key findings and demonstrate the potential areas for additional research.

(i) Production perspective: How much energy can CBDC potentially use? Which technical factors in CBDC design consume more energy than others?

There are still some misconceptions suggesting that CBDC and cryptocurrencies are identical. Critics have raised concerns that the mining of Bitcoin and similar cryptocurrencies pollute the planet because they require a huge amount of energy that currently generates a huge volume of greenhouse gas emissions. (However, the relevant consumption index is accompanied by suggestions that mining could use renewable sources of energy, accommodate grid demand variability, and even soak up surplus energy that would otherwise have been wasted).[13] Hence, some are concerned that CBDC will also adversely affect the environment. It is important to address the intrinsic characteristics of CBDC, how it works, and identify differences between other cryptocurrencies to establish the likely environmental impact of CBDC. Therefore, this Note will explore how CBDC is different from cryptocurrencies and compare design options for CBDC and their energy consumption.

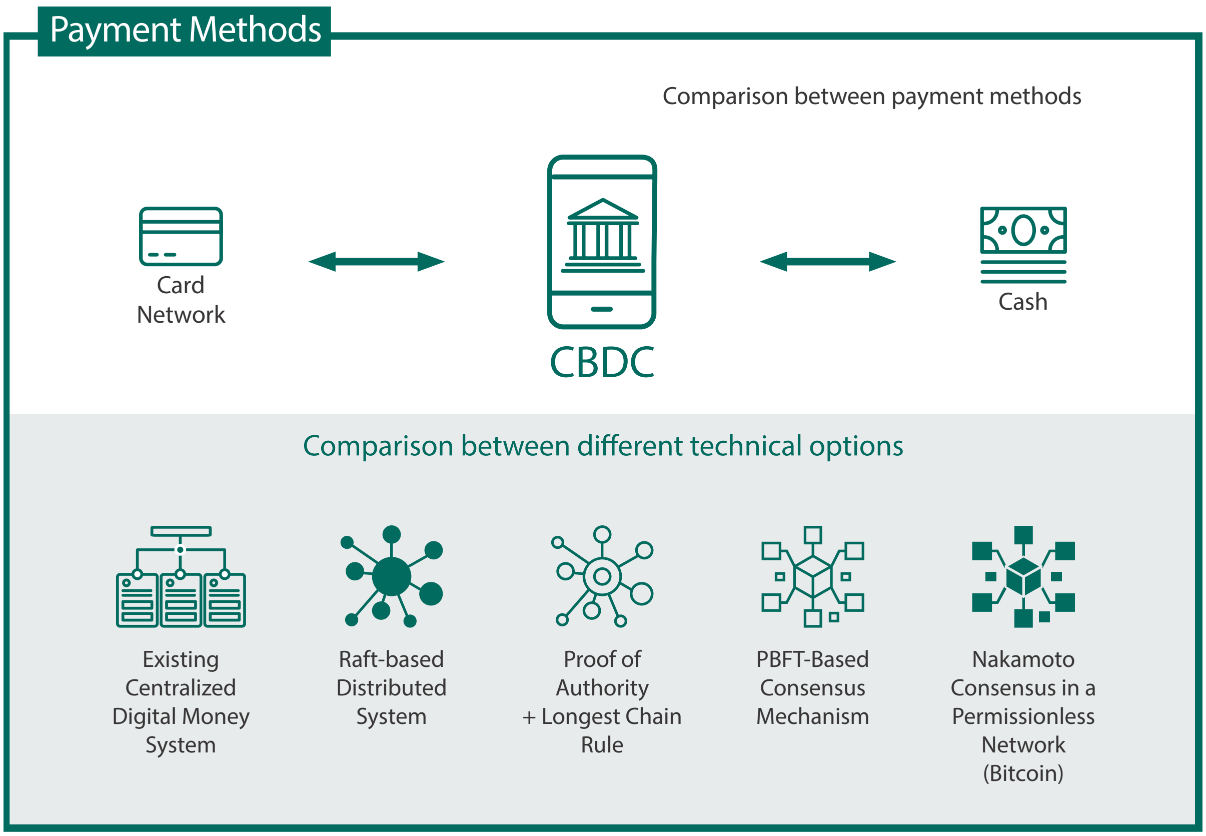
(ii) Circulation perspective: Does CBDC consume less energy than other payment methods? If so, how? What lessons can be learned from other payment methods?

Along with the review on the intrinsic characteristics and infrastructure of the CBDC—

10 "G7 Public Policy Principles for Retail Central Bank Digital Currencies" Accessed November 4, 2021.
11 "Report on a Digital Euro – European Central Bank." Accessed November 4, 2021.
12 "The Bank of England's Climate-Related Financial Disclosure 2021." Bank of England, November 1, 2021.
13 See, Cambridge Bitcoin Electricity Consumption Index, University of Cambridge Center for Alternative Finance, Accessed June, 2022

how the production and lifecycle of CBDC will impact environmental aspects—this Note also tries to compare it with other payment methods in order to make a comparative estimation. Comparison with other payment methods will provide an opportunity to gauge CBDC's environmental footprint and support a comparative interpretation of its level of impact.

Figure 2. Conceptualization of the comparison methods



Source: Author

III. CBDC Technology: How it works and what makes it different

To consider the environmental impact of CBDC, it will help to understand the technologies that can be used for CBDC and their differences from current payment methods. This section introduces the concepts and differences in the technological structure behind the current payment & settlement system and cryptocurrency. Then it explores the question of which technical stacks of CBDC can be related to environmental implications, which solution may (or may not) be relevant to environmentally friendly CBDCs, and what should be considered when designing the system.

1. Current Payment System & Real-Time Gross Settlement (RTGS) System

Let's think about how the bank system usually processes money transfers. When you want to send money using a smartphone to your friend, you select your account and enter the transfer amount and your friend's account. As you touch *confirm,* the transaction information is sent to the server of the bank through the internet. Then the bank system checks its databases to see if the transaction is valid: if you are the owner of the account from which a withdrawal is requested, if the account balance is sufficient, if the destination account exists, and so forth. If the transaction is valid, the transaction is recorded in the database, and the balance of your and your friend's accounts are updated accordingly. Then the system notifies you and your friend that the transfer is completed. And, if your account and your friend's account belong to different banks, the transaction should be settled between the banks. There are several approaches to this settlement process. Banks can settle the entirety of a day's transactions between themselves, or banks can send transactions to a settlement agent, who settles the transaction on their behalf. As direct settlement between banks becomes complex (with an increasing number of banks), the settlement process through trustworthy agents is generally seen as the efficient alternative. A central bank usually acts as a settlement agent because every payment service provider, including banks and other financial institutions, should hold accounts in the settlement system.

As the digital transformation accelerates, central banks adopt a real-time gross settlement (RTGS) system, which has the potential for CBDC use. Compared to the conventional settlement system that settles periodically, RTGS settles the transaction in real time, diminishing settlement risks such as liquidity shortage. This RTGS system can be used to issue CBDC, because it has functions to manage accounts, balances, and settlement processes.

2. Distributed Ledger Technology & Blockchain

Blockchain technology came into the spotlight with the growth of cryptocurrencies, and its concept of digital money with technically established legitimacy drew the attention of the central banks considering CBDC. At a basic level, a cryptocurrency such as Bitcoin is based on blockchain technology. Blockchain is a specific type of distributed ledger. Distributed ledger technology (DLT) is the infrastructure and protocol that stores transaction records in the ledger and ensures sharing of the same ledger records among the distributed network participants. Blockchain is a distributed ledger that prevents double-spending without a trusted third party, using a consensus mechanism that defines the canonical state of the ledger.

DLT/blockchain can be used to record the transactions as a substitute for the database within the real-time gross settlement (RTGS) system. CBDC system can be designed in a hybrid form best understood as related to—yet distinct from—both a centralized RTGS system, and a blockchain-based system.[14] The difference between them is that the blockchain system uses a more robust consensus mechanism to ensure the ledger records are correct even in a hostile environment.

3. A Deeper Look at Blockchain & Underlying Consensus Mechanisms

Technically, blockchain refers to its data structure. Transactions that are recorded on the ledger are grouped into blocks, and each block is linked to the previous block by using a hash value calculated based on the previous block and transactions in the current block. The word "blockchain" came from this linked-block structure. This structure makes the ledger hard to be modified because the hash value is unique; therefore, if someone wants to modify a transaction in a past block, they should update not only the target block but also the whole blockchain following the block. In the Bitcoin network, miners create and propose blocks and receive mining rewards if the block is accepted. Therefore, miners record the transaction into the ledger, which means miners can decide which transactions would be recorded or not and which transaction would be recorded first. Furthermore, double spending can happen when several blocks of the same miner are accepted sequentially. Thus, it is important to decide who will be the block creator.

4. Opportunities in CBDC Design

The Bank for International Settlements (BIS) identified the design areas for CBDC as the legal claim structure of CBDC: a choice between an RTGS system and blockchain, between an account and token-based method, and between wholesale and retail use.[15] The European Union Blockchain Observatory & Forum (EUBOF) selected the access method (account-based or token-based), the ledger infrastructure (RTGS or blockchain), and the management (centralist or federalist) as the CBDC design spaces.[16]

From these design spaces, the focus will be on the ledger infrastructure and the management structure as it is closely related to the consensus mechanism. Considerations for building the retail CBDC system can be applied similarly to the wholesale CBDC system; therefore, treating the two systems differently would not be appropriate here. Furthermore, the ownership verification method choice, account-based or token-based, does not make a big difference, including the environmental implications. Consequently, the next section will explore the choice between RTGS and DLT/blockchain and who will participate in the consensus mechanism. As previously discussed, the RTGS system can be utilized to issue CBDC,

14 George Giaglis et al., "Central Bank Digital Currencies and a Euro for the Future," The European Union Blockchain Observatory & Forum (EUBOF), 2021.

15 Raphael Auer and Rainer Böhme, "The technology of retail central bank digital currency," BIS Quarterly Review, March 2020.

16 George Giaglis et al., EUBOF, 2021 (see earlier footnote).

as it has functions to manage accounts, balances, and settlement processes.

IV. Environmental Implications of RTGS, Blockchain, and Consensus Mechanisms

1. Ledger Infrastructure: RTGS versus Blockchain

In designing CBDC, the selection of a ledger infrastructure is important. A choice between RTGS and Blockchain— that is to say, between centralized and distributed ledger infrastructure, respectively— can vary based on its priorities and objectives, and it will make a difference to security level and computation cost, affecting energy consumption.

Many countries are using RTGS or RTGS-equivalent systems for the settlements between banks.[17] Several countries recently implemented a new RTGS system (EU, Australia, Hungary, Hong Kong, Brazil) or are planning to develop one (US, Sweden).[18] RTGS systems achieved high resilience and performance with continuous effort and have already been tested and used in the field for many years.

Compared to the RTGS system, the key strength of the blockchain system is the absence of a single point of failure (SPOF). A SPOF is a part of a system that stops the whole system's operation when the part fails to work correctly. As a SPOF can be a target of attack by malicious players, eliminating SPOFs is one of the key objectives for a system required to operate continually without interruption. Blockchain technology is built to operate properly even when some network participants are malicious. Therefore, adopting the blockchain technology appropriatelyor the CBDC system might help achieve higher resilience.

This advantage of blockchain technology derives from the consensus mechanism within its distributed structure. This is the most significant difference between the RTGS-based system and the blockchain system, and the difference extends to environmental impact. Compared to RTGS-based systems, blockchain systems require additional computations to achieve the consensus without having SPOFs. This computation cost affects the system's energy consumption. The cost varies depending on the consensus mechanism adopted. For example, a blockchain mechanism with the least additional computations will not be different from an RTGS-based system in terms of energy consumption. [19]

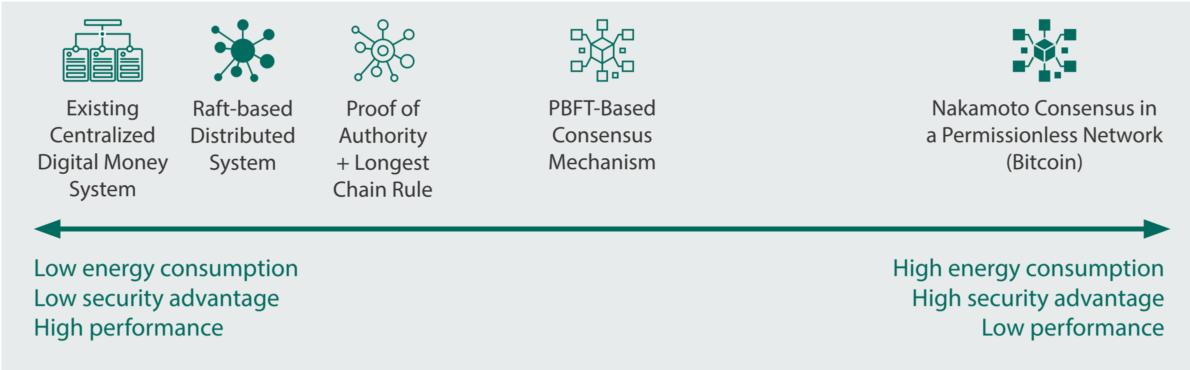
Therefore, it would be better to choose RTGS if reducing the energy consumption in CBDC is the top priority, because the blockchain system would incur additional energy consumption, albeit often very marginally. However, national authorities will want to consider the merits of using blockchain, depending on the objective of the CBDC system, as it can offer unique security advantages.

2. Environmental Implications of Consensus Mechanism

After choosing blockchain technology as a design option for ledger infrastructure, it is time to choose the appropriate consensus mechanism that meets the overall objectives of the system. The key to the blockchain operation is the maintenance of the consensus of the information recorded on the blockchain within the network, which impacts the financial parameters and security of the operations. There are various consensus mechanisms with different characteristics that will affect the different energy consumption levels. Figure 3 shows a conceptual summary of the environmental implications, security advantages, and performances in general. There are various other combinations with a Sybil resistance mechanism and a consensus protocol (not included here), and details can vary depending on the implementation.

Figure 3. Conceptual summary of tradeoffs between CBDC design choices

17 Morten Bech, Yuuki Shimizu and Paul Wong, "The quest for speed in payments," BIS Quarterly Review, March 2017
18 Jinwook Jang and Hyung geun Yoon, "A case of introducing a rapid fund transfer system using Real-Time Gross Payment (RTGS) method in major countries", Bank of Korea, March 2021.
19 George Giaglis et al., EUBOF, 2021 (as above).



Source: Author

Along with its intrinsic operating mechanism, the number and the distribution of the participants can also affect the energy consumption depending on the consensus protocols. For example, computation cost increases linearly as the number of participants grows when validating themselves but increases exponentially under Practical Byzantine Fault Tolerance (PBFT)-based consensus protocols.[20] Limiting the number of participants can save energy, especially for PBFT-based mechanisms, but that will reduce the security advantages and multiply vulnerabilities to attack. Also, from the distribution perspective, having many nodes within a single space, or managed by a single entity, does not give a massive advantage in terms of security and can be a SPOF. However, having many different entities participating as a node operator can also incur high management costs and privacy-related issues in addition to the environmental implications.

Therefore, it is important to understand that there is no silver bullet. Making design choices for CBDC with an understanding of the tradeoffs and the consideration points would be essential.

V. Comparing CBDC's environmental footprint with other payment methods

1. Cryptocurrency

Intrinsic limitations will inevitably constrain efforts to design a completely energy-saving cryptocurrency. Current systems were designed to operate within a trustless environment, and an energy-intensive mechanism was adopted to achieve the goal. Therefore, under a decentralized ecosystem, it can be difficult for cryptocurrency networks to reduce the energy consumption level to that of existing money. High energy consumption and the negative environmental impact is considered a critical side effect of cryptocurrency; this raises concerns and impedes rapid adoption.[21]

Energy consumption can vary depending on the type of cryptocurrency and its underlying structure. For example, Ethereum, the second-largest cryptocurrency by market capitalization,[22] is currently using proof-of-work for its Sybil resistance mechanism. The Ethereum network is estimated to consume 87.97 TWh annually, which is comparable to Finland and Belgium's annual power consumption.[23]

In response to the increasing attention on sustainability, cryptocurrencies have recently adopted more eco-friendly consensus mechanisms. Several cryptocurrencies, such as Solana, Cosmos, Algorand, or Polkadot, use proof-of-stake, which consumes less energy than proof-of-work. Ethereum is also planning to switch to proof-of-stake in the first or second quarter of 2022.[24] Ethereum Foundation estimates that the transition to proof-of-stake will reduce its energy consumption by at least 99.95%.[25] Cambridge Center for Alternative Finance (CCAF) also indicates that mining could utilize renewable and stranded sources of energy.[26]

20 The Practical Byzantine Fault Tolerance (PBFT) is a consensus protocol that validates the transactions in the block and creates consensus for each block with explicit voting between the consensus process participants.
21 Browne, Ryan. "Why Everyone from Elon Musk to Janet Yellen Is Worried about Bitcoin's Energy Usage." CNBC, May 2021.
22 "Cryptocurrency Prices by Market Cap", Coingecko, Accessed November 15, 2021
23 Ethereum Energy Consumption Index", Digiconomist, Accessed November 15, 2021
24 "The Merge", Ethereum Foundation, last modified August 19, 2021, Accessed November 15, 2021
25 Carl Beekhuizen, "A country's worth of power, no more!", Ethereum Foundation (blog).
26 Cambridge Bitcoin Electricity Consumption Index, University of Cambridge Centre for Alternative Finance, Accessed June, 2022

While a crypto asset's intrinsic structure requires considerable energy, CBDC is in a different energy-consuming structure. Because it is backed by the central bank, it does not need to earn its trust in a trustless environment like Bitcoin,[27] and its environmental fingerprint will be more comparable to existing digital money systems than cryptocurrencies.[28]

2. Cash and card network

Although comprehensive hypotheses and assumptions must remain imperfect, there has been an effort to verify the climate impact of payment methods. De Nederlandsche Bank (DNB), the central bank of the Netherlands, evaluated the environmental impact of debit card payments by using a life-cycle assessment.[29] DNB indicated that the total ecological impact of a cash payment is 1.5 times higher than that of a debit card payment. Ripple, a blockchain-based payment protocol company, measured the environmental impact of cryptocurrencies, cash, and card networks (Visa and Mastercard). As seen below in Table 2, it is estimated that card networks use less energy than blockchain assets and cash.

Table 2. Latest available estimate of electricity consumption per transaction

Type	Blockchain Asset			Cash	Network	
	Bitcoin	Ethereum	XRP	Paper money (US)	Visa	Mastercard
Electricity consumption per transaction (kWh)	700 (2020 YTD)	30 (2020 YTD)	0.0079 (2019)	0.044 (2018)	0.0008 (2018)	0.0006 (2018)

Source: Ripple. "Measuring the Environmental Impact of Cryptocurrency." (2020)

Tracing the energy consumption throughout the entire lifecycle of paper money is difficult because the process varies by country and use of raw materials. However, there have been many efforts to estimate it based on multiple methodologies. A study by S. Rochemont focused their methodology on printing notes and note circulation.[30] According to the research, the average electricity cost for the United States Bureau of Engraving and Printing bill manufacturer corresponds to 11.38 cents/kWh (an average 2018 household electricity unit cost in Texas). Also, the research shows that automated teller machine (ATM) energy consumption is a dominant factor impacting energy consumption and estimates that 0.84 TWh was consumed by ATMs in the United States annually.[31]

The card network, including debit and credit cards, consumes much less electricity than other payment methods. Companies such as Visa and Mastercard pledge net-zero emissions to create a more sustainable and inclusive digital economy and make efforts to reduce their electricity consumption per transaction. Current business electricity consumption and data center specific consumption have been captured—the numbers are minimal. It is estimated that the energy consumption corresponding to each Visa and Mastercard transaction is 0.0008kWh and 0.0006kWh respectively. Clearly, these amounts are far less than those of cryptocurrencies and paper money.

CBDC will be in the form of digital money. The BIS reported that a CBDC is a digital payment instrument denominated in the national unit of account that is a direct liability of the central bank.[32] In a CBDC world, each virtual currency unit will have a unique digital code in a digital wallet and will be transferred seamlessly by the wallet-holder to other digital wallets of individuals. It is very similar to what we see in today's fintech and other digital wallets provided by big tech companies, including mobile payment apps and wallets offered by traditional banks that do not require the exchange of paper money.

Most of the current CBDC projects are using a hybrid CBDC where the accounts represent a liability of the central bank, but private intermediaries can handle retail payments. ECB pointed out that "a parallel infrastructure

27 "Central Bank Digital Currency: An update on the Bank of England's work – speech by Tom Mutton", Bank of England, June 17, 2021.
28 George Giaglis et al., EUBOF, 2021 (as above).
29 De Nederlandsche Bank, "Life cycle assessment of cash payments," October 2018.
30 S. Rochemont, "A cashless society: benefits, risks, issues," Institute and Faculty of Actuaries, October 2018.
31 "Measuring the Environmental Impact of Cryptocurrency." Ripple. Accessed November 20, 2021.
32 "Central Bank Digital Currencies: Foundational Principles and Core Features, Report No. 1" Bank for International Settlements (2020).

would also run counter to the aim of issuing a digital euro in order to improve the cost and environmental footprint of payments."[33]

Although there are still limitations that cannot yet be overcome when directly comparing the ecological footprint of future CBDC and other payment methods, studies show that crypto assets consume the most energy, followed by cash and the card network. While the card network has the least environmental impact from the perspective of energy consumption, the payment method with the most similar characteristics and infrastructure to it is CBDC.

VI. Conclusion

This Note tried to address considerations around the environmental impacts of CBDC, explored the differences between various design options, and compared them with the existing payment systems to raise awareness among central banks, regulators, and policy makers on the environmental implications of CBDC. While this Note is focused on the EAP audience, the issues to be considered as outlined below can be applicable to countries in other regions as well. Below are the key considerations we would like to highlight.

1. Central banks, especially in EAP, need to consider the environmental impact of CBDC

Two-thirds of central banks in the EAP region carry out CBDC-related research or have conducted implemental preparations. Research on EAP vulnerability to environmental impact indicates that central banks in the region may need to carefully consider CBDC's environmental impact and potential climate risks. The EAP region is one of the key contributors to rising greenhouse gas emissions. Six countries in the region have been identified as the most vulnerable to climate change and comparatively more vulnerable to environmental risks. Considering these characteristics, central banks in the EAP region should consider the environmental impact and potential climate risks while exploring and adopting CBDC.

2. Environmental impact will vary depending on CBDC Design Options

CBDC could be a catalyst for financial innovations; however, careful deliberation is required to balance the objectives and their implications. Based on their own circumstances, central banks are exploring CBDC with various objectives, including resiliency and inclusive payment services. The environmental impact of design choices in ledger infrastructure and consensus mechanism choices can vary, and the choice entails tradeoffs between energy consumption, security advantage, and performance. The tradeoffs of design choices are intimately bound up with the objectives, such that the pursuit of one aspect can make it hard to achieve other goals. Therefore, the CBDC objectives and design decisions should be carefully balanced on the priorities with comprehensive research from a holistic viewpoint.

3. Importance of assessing technology choices to meet strategic and environmental goals

CBDC is not tied to a single technology, and both blockchain and digital payment solutions can be adopted. Blockchain technology is not a mandatory requirement for CBDC, and the existing digital payment solutions like an RTGS-based system or a credit card payment system can also be utilized for CBDC. The outputs and environmental risk can be different depending on technology choices. For example, CBDC is expected to consume less energy than that of cryptocurrencies, with energy consumption similar to that of card networks or mobile payments. Therefore, it is critical for national authorities to assess how each technology might meet both their strategic goals and environmental objectives and choose the optimal option—the one most conducive to long-term financial stability.

CBDC is in the early stage of exploration, yet its development is rapidly evolving. Considering the socioeconomic impacts of CBDC, it is important to consider the environment and climate strategy to achieve long-term financial sustainability. This Note seeks to address some of the initial ideas and assumptions to tackle this problem and the research and results of this Note will lead to further research. Moving forward, development of CBDC and the accumulation of relevant data will support a better projection on carbon footprint.

33 European Central Bank, "Report on a digital Euro", October 2020.

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