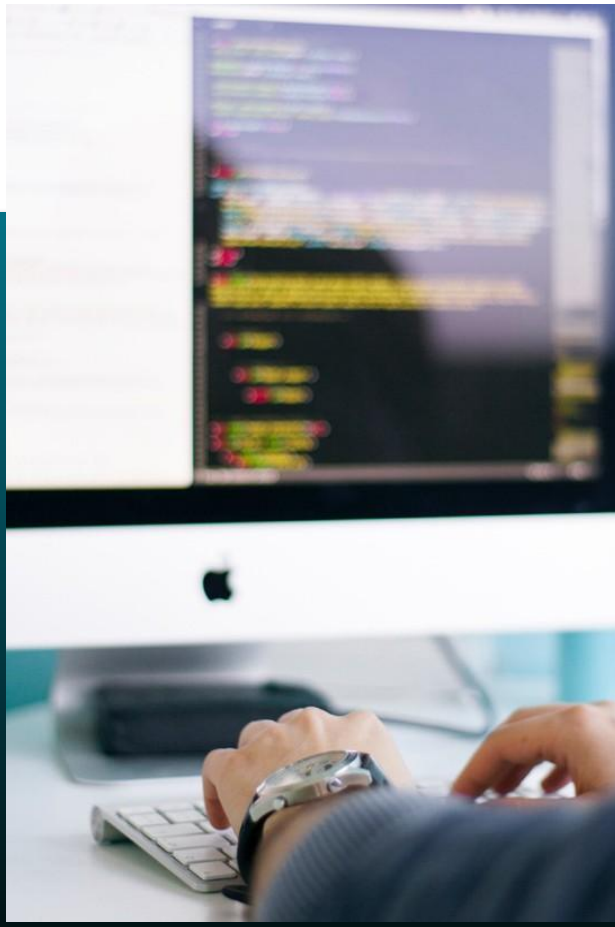
Hyperledger
FOUNDATION

Hyperledger in Action

Central Bank Digital Currencies v2

Contents



Introduction

As central banks around the world have explored and researched the uses, viability, and needs for a central bank digital currency, Hyperledger's distributed ledger technologies (DLTs) have been at the forefront of these experimentations.

Hyperledger DLTs, built in the open with vendor-neutral governance and currently deployed in several production networks in other sectors, provide proven technology with strong community support.

Central banks want to know that the technology they are using is sustainable, tested, and can withstand and adapt to the unique needs of this use case.

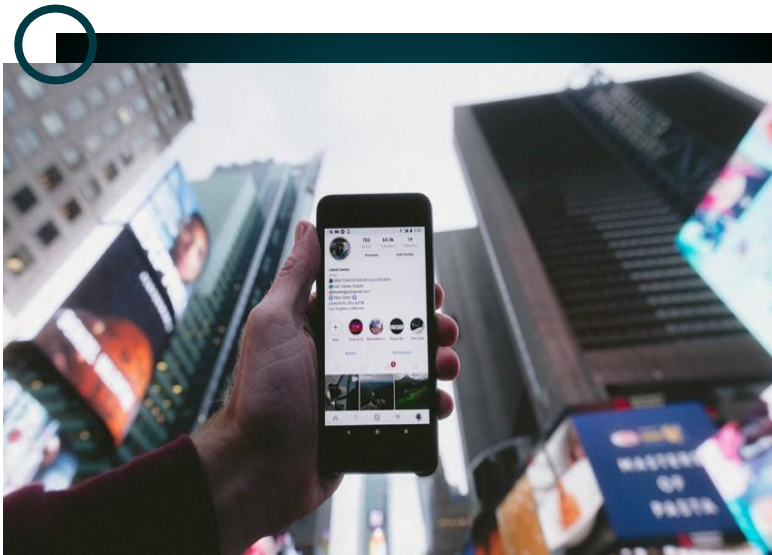
We expect there will be many different DLTs used and explored for CBDCs and are proud to share these examples of how Hyperledger technology is leveraged and trusted for DLT-based CBDCs.

We believe that for such an essential public good as digital cash, the technology that the future of money is built on should come from communities working together in the open, sharing ideas, knowledge, and lessons learned, to improve and test in a shared environment that everyone can benefit and learn from.

This ebook provides the reader an overview of the Hyperledger Foundation, why open source development is appropriate for all central bank projects and real-life examples of CBDC projects around the world.

> *"Open source motivates higher-quality code. Everyone doing open source cares a lot more about the code they write, because they know anyone can see it."*

Makoto Takemiya
CEO and co-founder at Soramitsu
(Development company on Project Bakong - National Bank of Cambodia (NBC)



Hyperledger Foundation

An Overview of the Foundation

What is Hyperledger?

This section provides a high-level overview of the Hyperledger Foundation.

Hyperledger Foundation

The Hyperledger Foundation is the open, global ecosystem for enterprise blockchain technologies. As part of the Linux Foundation, it is a neutral home for developers to collaborate, contribute, and maintain open source software.

Hyperledger was founded in 2015 to bring the transparency and efficiency of DLT technologies to the enterprise market, leveraging the well-proven open source software model.

The high level aim is to enable solutions that connect industries, organizations, and even individuals
more directly, recreating how information is shared and business is conducted.

The Hyperledger Foundation hosts a number of open source software projects that serve as the building blocks for enterprise blockchain deployments.

Read Full Overview:
Hyperledger Foundation Paper

These projects are conceived and built by the Hyperledger developer community as freely available, enterprise-grade software that vendors, end user organizations, service providers, start-ups, academics, and others can use to build and deploy blockchain networks and even commercial solutions.

Because our projects are developed and governed as open source technologies, Hyperledger projects are all community led.

Open Source Development

Open source software development is a transparent process, which is particularly fitting for blockchain technologies. It brings together organizations and individuals with different requirements and drives them to work together to develop common solutions that can be the foundation for mutual success—another good parallel with blockchain.

Hyperledger Foundation Goals

Provide a neutral, open community around enterprise blockchain supported by technical and business governance

Foster the development and adoption of cross-industry platforms powered by distributed ledgers

Educate the public about the market opportunity for enterprise grade blockchain technology

CBDCs and Open Source

According to the Federal Reserve, the central bank of the United States, central bank money traditionally takes two forms: cash and reserves held by eligible financial institutions at the central bank.

Central bank digital currency (CBDC) is a generic term for a third version of currency that could use an electronic record or digital token to represent the digital form of a nation's currency.

A CBDC is issued and managed directly by the central bank and could be used for a variety of purposes by individuals, businesses, and financial institutions.

Central bank digital currency projects are moving quickly from prototypes to pilots and beyond with some well known projects already in production.

As CBDCs and other cross border payment use cases mature, central banks continue to partner with the private sector from small to big companies to accelerate and innovate,

and Hyperledger technologies, built by our open source community, are at the forefront of most public CBDC projects.

In addition to developing products and services which many of deliver to their central bank customers, the Hyperledger community is also working to build the future of digital money with open source principles and goals.

Technology innovation happens when companies, developers, academics, and regulators come together to meet common goals, and Hyperledger Foundation is proud to host the development of code that will enable payment innovations around the world.

CBDCs will be a game-changing public good that we believe should be built in an open and collaborative manner.

Hyperledger Projects

A distributed ledger is a multiparty database with no central trusted authority. When transactions are processed in blocks according to the ordering of a blockchain, the result is a distributed ledger. Hyperledger Foundation hosts a variety of platforms that serve as the foundation for blockchain networks across a range of industries and use cases.

HYPERLEDGER BESU

Hyperledger Besu is an Ethereum client designed to be enterprise-friendly for both public and private permissioned network use cases. It can also be run on test networks such as Rinkeby, Ropsten, and Görli. Hyperledger Besu includes several consensus algorithms including PoW, and PoA (IBFT, IBFT 2.0, Etherhash, and Clique). Its comprehensive permissioning schemes are designed specifically for use in a consortium environment. Learn More

HYPERLEDGER FABRIC

Hyperledger Fabric is intended as a foundation for developing applications or solutions with a modular architecture. Hyperledger Fabric allows components, such as consensus and membership services, to be plug-and-play. Its modular and versatile design satisfies a broad range of industry use cases. It offers a unique approach to consensus that enables performance at scale while preserving privacy. Learn More

HYPERLEDGER IROHA

Hyperledger Iroha is an easy to use, modular distributed blockchain platform with its own unique consensus and ordering service algorithms, rich role-based permission model and multi-signature support. Learn More

HYPERLEDGER CACTI

Created by the merger of two systems (architectures as well as code bases), Hyperledger Cacti is a multi-faceted interoperability platform that draws on the cutting-edge technical features of Hyperledger Cactus and Weaver, a Hyperledger Lab. Learn More

HYPERLEDGER FIREFLY

Hyperledger FireFly is the first open source Supernode: a complete stack for enterprises to build and scale secure Web3 applications. The FireFly API for digital assets, data flows, and blockchain transactions makes it radically faster to build production-ready apps on popular chains and protocols. Learn More

Photo by CHUTTERSNAP on Unsplash

Community Work with CBDCs

As you will see throughout this ebook, the Hyperledger community is actively advocating, developing and deploying digital currencies including those issued by central banks.

The Hyperledger team, working with our Foundation members, have been following closely the activities and projects that are using Hyperledger technology.

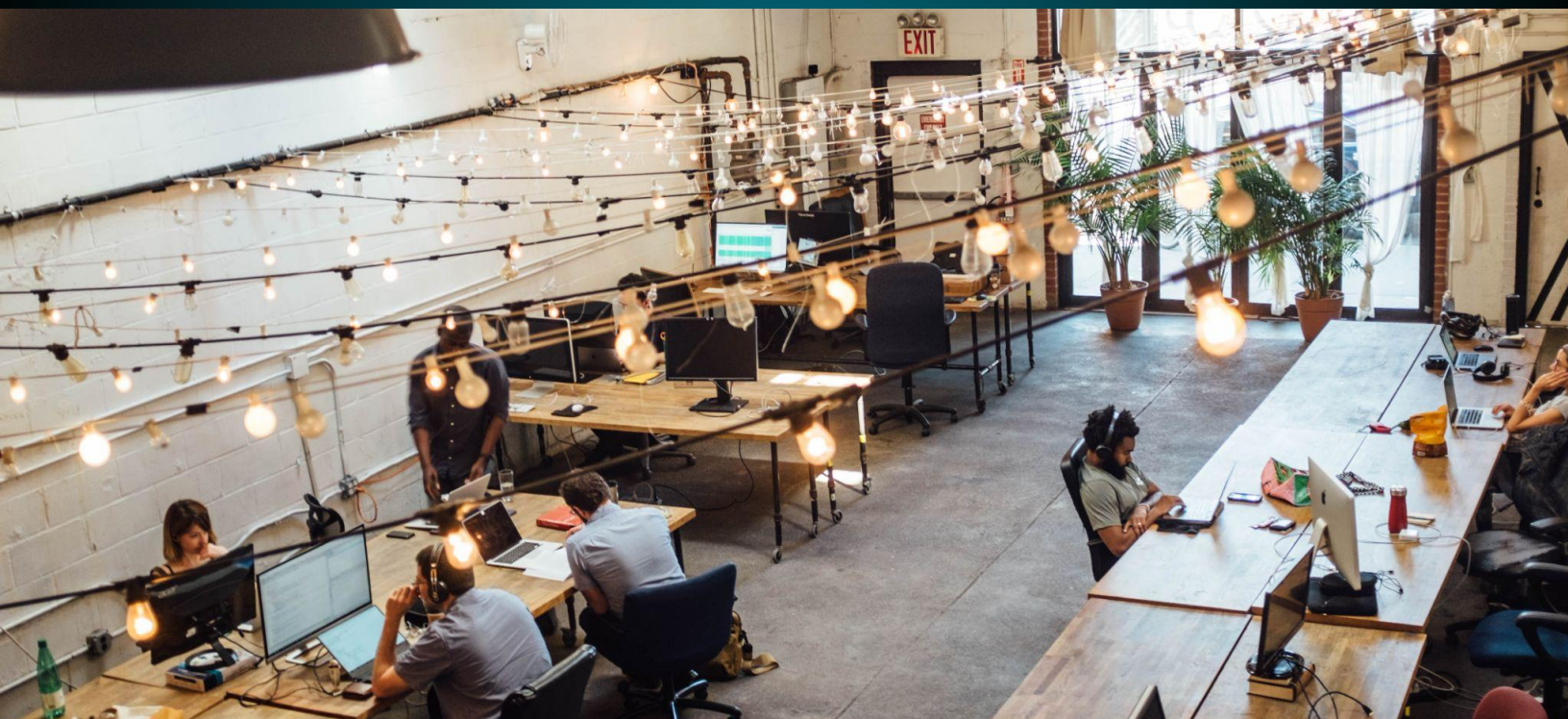
We know there are many public and not-yet-public examples exploring and using Hyperledger Besu, Hyperledger Fabric, and Hyperledger Iroha, as well as other DLTs.

We hope this overview provides you with a good summary of those efforts.

How else can you get involved in this work happening at Hyperledger Foundation?

- Join as a Hyperledger Foundation member. Our member companies are leaders in financial services and technology working on these exciting projects. Learn more about membership.
- Download and learn more about our Projects: https://www.hyperledger.org/projects
- Participate in our open communities, like our Financial Markets SIG.
- Deep dive into Hyperledger projects with training and certifications.
- Attend other Hyperledger events and webinars.

Photo by Shridhar Gupta on Unsplash



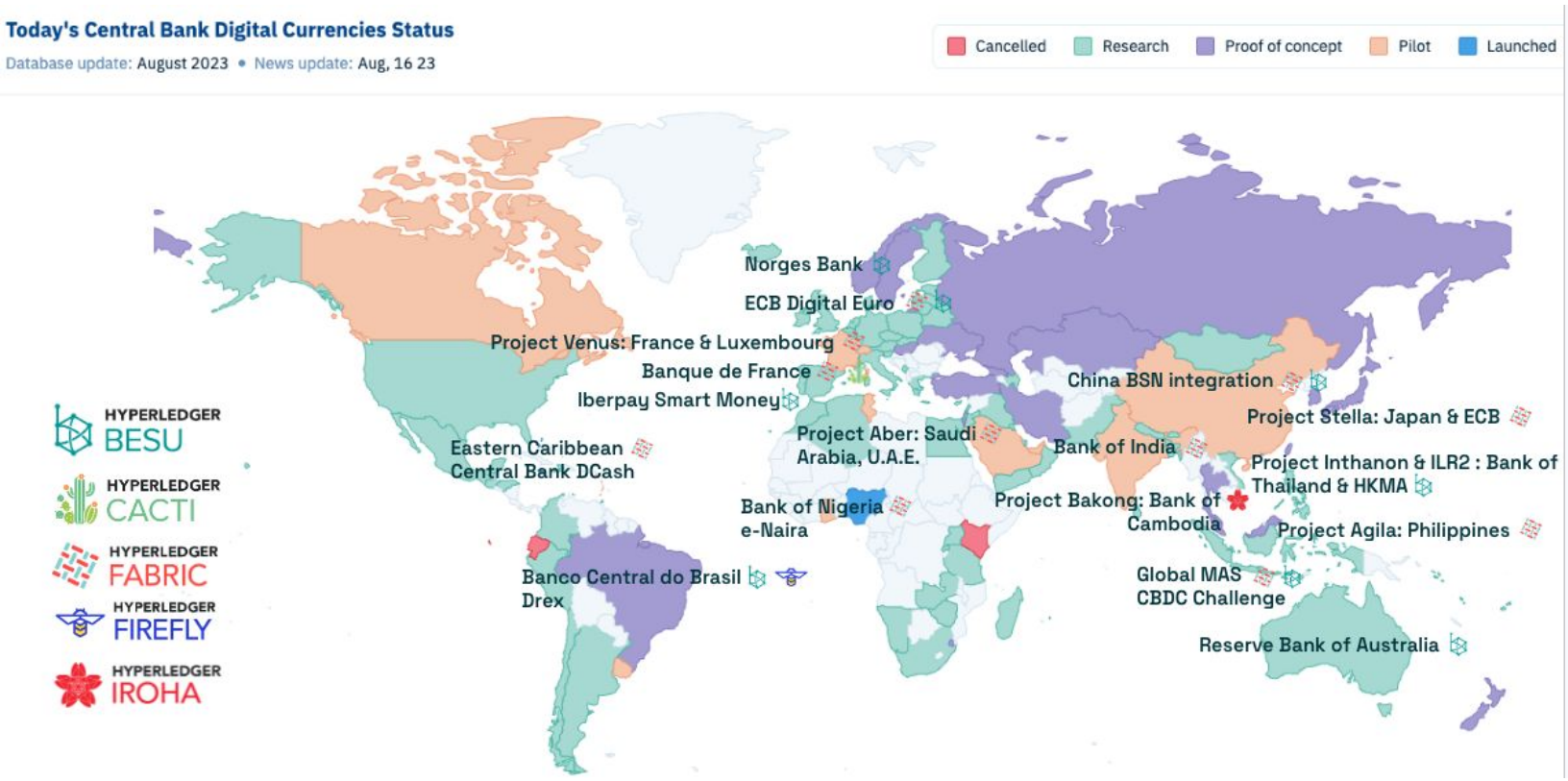
CBDCs Around the Globe

Hyperledger in Action by Region

Photo by Helena Lopes on Unsplash

Hyperledger Technologies in Action

CBDC Projects & Experimentations with Hyperledger Tech Around the World



*publicly announced - CBDC Tracker; bis.org

PHASE: RESEARCH

European Central Bank

ECB President Christine Lagarde has suggested that a digital euro can complement cash. Furthering the exploration of a digital euro, the European Central Bank released research on a tiered approach to test how centralized systems could operate with distributed ledger technology.

Several European banks participated including the central banks of Spain, Italy, France, Lithuania, Luxembourg, Belgium, and Austria.

The research found that Hyperledger Besu and Hyperledger Fabric, amongst others, were "fully interoperable with existing fiat systems". Read the full report here.

The ongoing investigation lasting from Oct 2021-Oct 2023 includes a latest progress update focusing on researching demand, compensation model, a high-level design review and distribution of a digital europe.

The ECB Governing Council will decide in October 2023 whether it plans to proceed to the next phase of preparing for the issuance of a digital euro.

Image Copyright: Digital Euro experiment report

PHASE: RESEARCH

France

In 2020, Banque de France conducted its first experiment, partnering with Hyperledger Foundation Premier Member IBM, on the tokenization of government bonds and their distribution in primary and secondary markets via CBDC.

Smart contracts implemented automated processes such as auto-collateralization, on-flow, and coupon payments. The experiment leveraged Hyperledger Fabric and Token SDK, a Hyperledger Lab. In 2021, Banque de France completed a trial for a wholesale CBDC, partnering with HSBC, and eight other organizations. This final stage of the experiment tested the interoperability between a CBDC blockchain network and a bond network using Hyperledger Fabric, Cacti, and R3 Corda, respectively, for the DLTs and Hyperledger Labs' Weaver as the interoperability tool.

In July 2023, they released a final report with conclusions of the total of 12 experiments that took place since 2020. The Banque was able to demonstrate the operational feasibility of 3 models for a wholesale CBDC: interoperability, distribution, and integration. Each offers different capabilities and has been tested with many different use cases in the areas of tokenization of finance and cross-border transactions.

Overall they were able to demonstrate that tokenizing central bank money would improve cross-border payments, settlement finality, security and more, and that it is feasible operationally.

Banque de France has also participated in Project Mariana with BIS and Monetary Authority of Singapore, using Hyperledger Besu, with a focus on CBDCs in automated market makers.

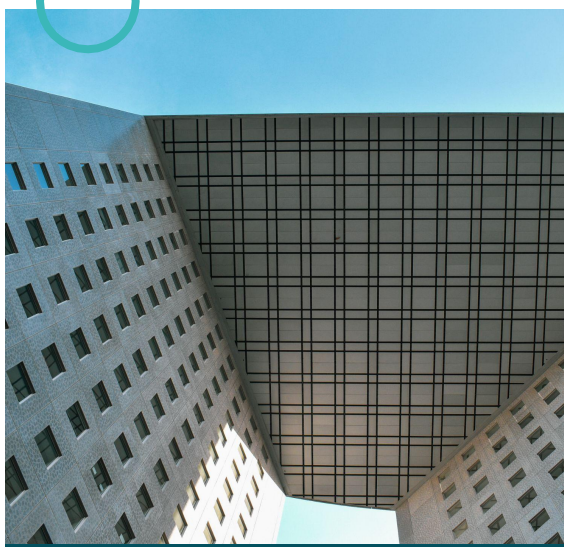


Photo by Tanguy Belin on Unsplash

Please visit IBM for more information on blockchain-based CBDC architectures.

PHASE: PILOT

India

In October 2022, The Reserve Bank of India announced that it was launching a pilot for a wholesale and retail CBDC, the Digital Rupee, with the aim to reduce operational costs in physical cash management, increase efficiency for settlements, payments system innovation, and to foster financial inclusion.

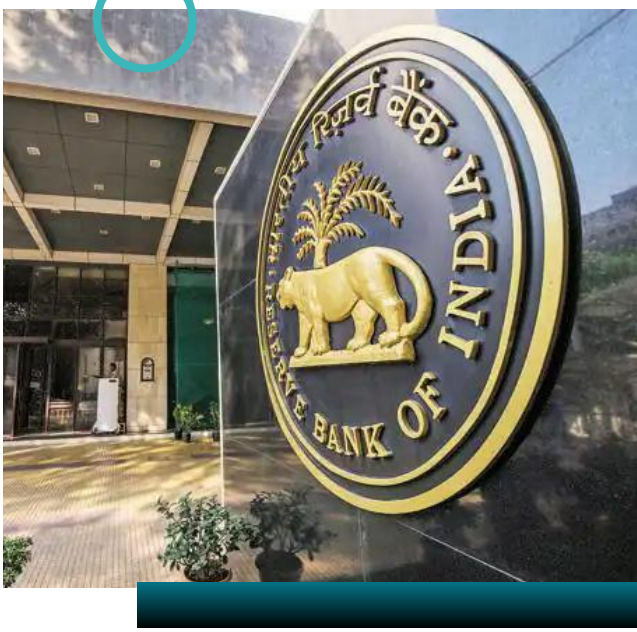
They endeavor to provide the Indian public with a risk-free digital currency that provides consumer protection.

By February 2023 the pilot had reached 5 cities amongst specific user merchant and customer groups. Leveraging Hyperledger Fabric as the DLT, features that RBI plan to incorporate are offline functionality, programmability, interoperability, and anonymity (owners of wallets will not be known to government or intermediaries).

More information on the design and rollout: Future of digital currency in India by PwC.

In an effort to test new markets, RBI announced that in October 2023 will extend the wholesale CBDC pilot to the interbank borrowing market. It was previously limited to secondary market transactions of government securities.

On the retail CBDC pilot, there is a ambitious target of reaching 1 million transactions by the end of 2023.



PHASE: RESEARCH

Swift Sandbox

In October 2022, Swift announced that they had developed a solution that facilitates transactions amongst CBDCs across DLT-based and fiat-based systems within the current day financial system.

They then embarked upon testing that solution with 18 central and commercial banks in a sandbox environment, including: Banque de France, Deutsche Bundesbank, Monetary Authority of Singapore, BNP Paribas, HSBC, Intesa Sanpaolo, NatWest, Royal Bank of Canada, SMBC, Société Générale, Standard Chartered, and UBS.

In this effort, Hyperledger Firefly was leveraged as the blockchain and digital assets platform for the sandbox. The testing phase lasted 12 weeks during which participants collaborated, tested, and provided feedback on the interlinking solution, the Swift CBDC connector and flows, the roles and responsibilities of those involved, and other considerations such as identity and privacy.

The sandbox testing found that the interlinking solutions can meet the needs for interoperable CBDC cross-border payments.

Future work is planned to extend interoperability, test further use cases, and extend testing to networks leveraging Hyperledger Fabric.

Read the report.

Please visit Kaleido for more information on blockchain-based CBDC architectures.

PHASE: PILOT

Brazil

After years of research and organizing the LiFT Challenge to explore use cases and MVPs, the Banco Central do Brasil announced June 2023 that it would be launching a CBDC pilot.

Its goals are to provide greater efficiency to financial markets and financial inclusion through Drex, previously referred to as the Real Digital, which will be implemented at the retail level via a regulated financial intermediary.

The Drex platform, built on Hyperledger Besu, will allow regulated financial intermediaries to convert balances of demand deposits and electronic money in Drex providing the market with new financial services enabled by smart contracts.

The International Monetary Fund (IMF) has praised Drex as its flagship initiative, stating that, "the Brazilian central bank is at the forefront of financial innovation," having already onboarded millions with its instant payment system Pix, the CBDC will build on it to allow for a "smart platform".

Please visit Consensys for more information on blockchain-based CBDC architectures.

PHASE: RESEARCH

Norway

Norges Bank is currently leveraging Hyperledger Besu in its multi-phase study of CBDCs. The latest phase 4 completed in June 2023 and phase 5 will until the end of 2025.

In Phase 4, a CBDC Sandbox was developed on Hyperledger Besu which allows the central bank to issue and send CBDC to a private bank who can distribute to their customers.

They demonstrated the ability to send thousands and millions of payments in a batch process leveraging APIs and smart contracts.

Phase 4 also included testing two capabilities that no other central bank has demonstrated before with a CBDC: verified credential functionality with the central social security registry in Norway and interest rate calculation on a per second basis for every transaction, mint and burn of the CBDC.

In Project Icebreaker, Norges Bank demonstrated for the first time, along with Bank of Israel, BIS, and Sveriges Riksbank, a cross border retail CBDC payment system.

It tested the technical feasibility between different DLT-based systems, and helped the parties understand the benefits, trade-offs, and challenges that could enable instant cross-currency transactions.

Please visit Consensys for more information on blockchain-based CBDC architectures.

Norges Bank has been a fast-moving innovator in its exploration of CBDCs.

In addition to the above they are unique amongst central banks as being **the first to publish their CBDC code openly to GitHub** for anyone to leverage.

We encourage more central banks to follow suit and share openly their CBDC code as a public good.

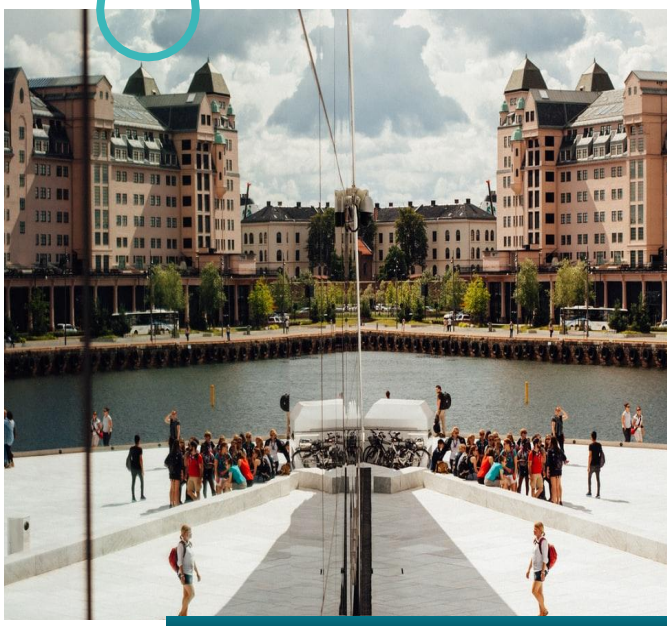


Photo by Oliver Cole on Unsplash

PHASE: PILOT

Philippines

In September 2023, Bangko Sentral ng Pilipinas (BSP) launched Project Agila to explore a wholesale CBDC pilot project.

BSP conducted a rigorous evaluation of distributed ledger technologies according to important characteristics such as 24/7 availability, security, interoperability, programmability and included in their announcement that they have selected Hyperledger Fabric for the project.

The aim of the project will be to establish a clearer understanding of CBDC technologies and whether a wholesale CBDC can advance the large-value payments system. Banks participating in the sandbox include:

BDO Unibank, Inc., China Banking Corp., Land Bank of the Philippines, Rizal Commercial Banking Corporation, Union Bank of the Philippines, and Maya Philippines, Inc.

The results and lessons learned of Project Agila will serve as input for the eventual CBDC project roadmap.

Please visit IBM for more information on blockchain-based CBDC architectures.

PHASE: RESEARCH

Thailand

Bank of Thailand's Project Inthanon was one of the first to demonstrate how blockchain can enhance efficiency and support innovations in payments and supply chain financing by leveraging CBDCs.

Hyperledger Foundation Member Consensys, alongside SCG and Digital Ventures, used Hyperledger Besu to meet both the functional and non-functional requirements of a retail CBDC.

One of the business cases tested the use of a CBDC to simulate daily commerce, automate payments, and support procurement and financial management system called Procure-to-Pay (B2P) developed by Digital Ventures.

Read the full report.

Please visit consensys.net for more information on blockchain-based CBDC architectures.

PHASE: RESEARCH

Inthanon-LionRock2 to Project mBridge

Project Inthanon-LionRock2 (ILR2), later renamed the mCBDC Bridge Project then Project mBridge, was led by the Bank for International Settlements HK Innovation Hub, Hong Kong Monetary Authority and Bank of Thailand.

Phase 2, leveraged Hyperledger Besu, produced a prototype that enabled central bank control and monitoring of flow, balances, and transactions with their respective CBDCs.

It demonstrated the ability to program privacy and automate compliance, as well as a significant increase in cross-border transaction speed and cost reduction.

For Phase 3, the People's Bank of China and the Central Bank of the United Arab Emirates joined the others to form the mBridge Project to demonstrate the completion of an international exchange of multiple CBDCs in seconds as opposed to several days.

Phase 3 also involved further experimentation with design and technology choices and a future roadmap for a production-ready network that will be open sourced for public use.

Read the full report.

BIS

中国人民银行
THE PEOPLE'S BANK OF CHINA

HONG KONG MONETARY AUTHORITY
香港金融管理局

HYPERLEDGER BESU

Please visit consensys.net for more information on blockchain-based CBDC architectures.

PHASE: LIVE

Cambodia

The National Bank of Cambodia's Project Bakong leverages Hyperledger Iroha and was recognized by PwC in 2021 in their Global CBDC Index as the #2 Retail CBDC globally and #1 in Asia.

They also received the 2021 Nikkei Superior Products and Services Award for economic and social impact.

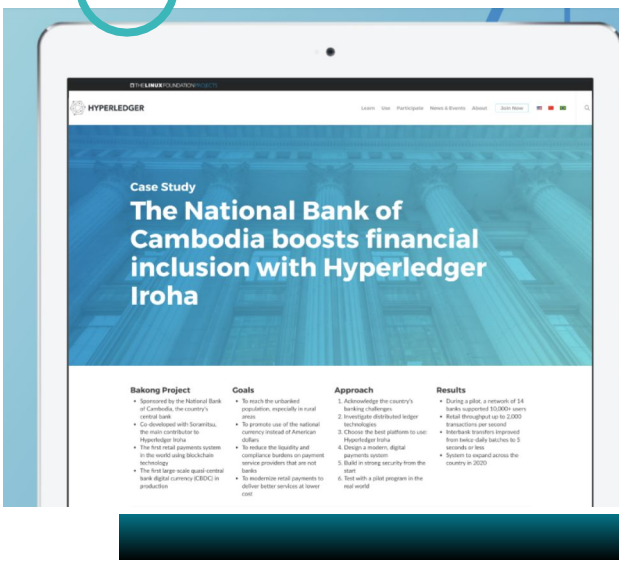
Bakong is the first large-scale blockchain-based central bank-run interbank payment system in production.

It is not quite a CBDC, but "a blockchain-powered retail payments system managed by the Cambodian central bank that allows interoperability among the different players in the country's payments landscape".

By June 2021 it had reached 200,000 users, doubling from three months earlier, amassing 1.4M transactions at a value of $500M.

As of July 31, 2022, Bakong had been used for 12.7 million transactions valued at US$7.2 billion.

Read more in the Hyperledger Case Study.



Please visit Soramitsu.co.jp for more information on blockchain-based CBDCs

PHASE: LIVE

Nigeria

The Central Bank of Nigeria launched the live eNaira CBDC in October 2021. One year later 700,000 transactions worth $18.3 million had been made on the eNaira's platform.

Two applications were made available to citizens, the eNaira speed wallet and eNaira merchant wallet. The government plans for a campaign to expand the use of eNaira among citizens and onboard more banks.

The main objectives for launching a digital Naira were to improve the availability and access to central bank money, tax and revenue collection, support a resilient payments system, enable efficient welfare distribution, and facilitate remittances and cross border payments.

In 2023, the eNaira will become available to those without bank accounts to expand adoption and inclusion.

Read the white paper for more information on the design and roadmap.

HYPERLEDGER FABRIC

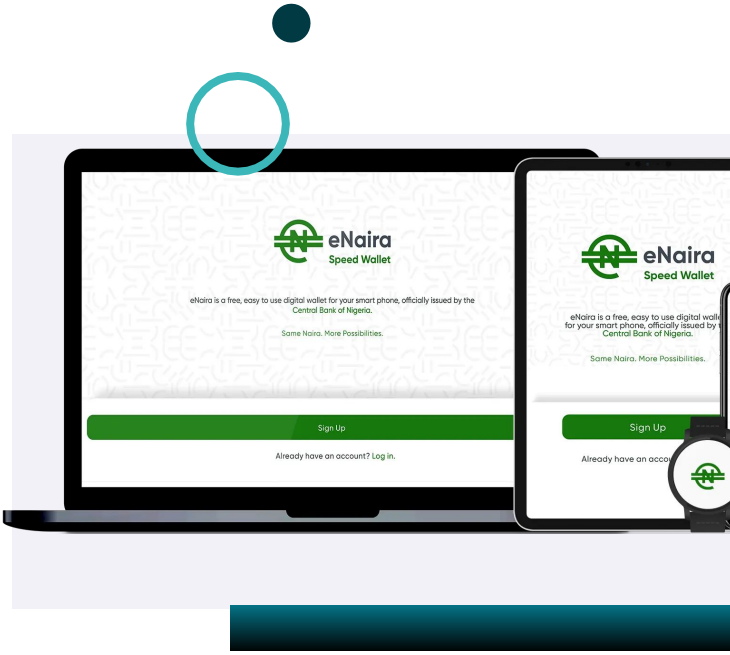


Image Copyright: eNaira

PHASE: RESEARCH

Spain

BANCO DE ESPAÑA
Eurosistema

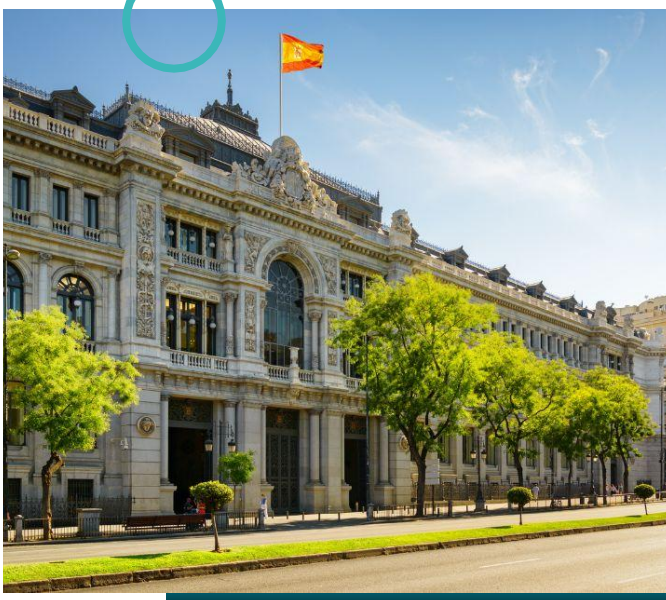
The Spanish financial sector completed the Smart Money experiment on the technical aspects of a digital euro's distribution, use, and design options.

The initiative–led by Iberpay, 16 banks (CaixaBank, Santander, BBVA, ING, etc.), and with the Bank of Spain observing–aimed to test the technical features outlined in the European Central Bank's report for a digital euro.

Using the Red-i blockchain network, based on Hyperledger Besu, Smart Money demonstrated the viability of a digital euro for the Spanish financial sector, including offline payments, and confirmed the two-tier infrastructure model as preferable over a centralized model.

Read the full report.

HYPERLEDGER BESU



Please visit Consensys for more information on blockchain-based CBDC architectures.

PHASE: RESEARCH

Australia

RESERVE BANK OF AUSTRALIA

Bank of Australia partnered with Consensys to develop a POC for the issuance of a tokenized form of CBDC that can be used by wholesale market participants for the funding, settlement, and repayment of a tokenized syndicated loan on a DLT platform.

Built on Hyperledger Besu it showed that an "enterprise-grade DLT platform with controls for access and security could address the requirements of a wholesale CBDC and tokenised assets platform."

Assistant Governor Michele Bullock said, 'Project Atom demonstrated the potential for a wholesale CBDC and asset tokenisation to improve efficiency, risk management and innovation in wholesale financial market transactions."

HYPERLEDGER BESU

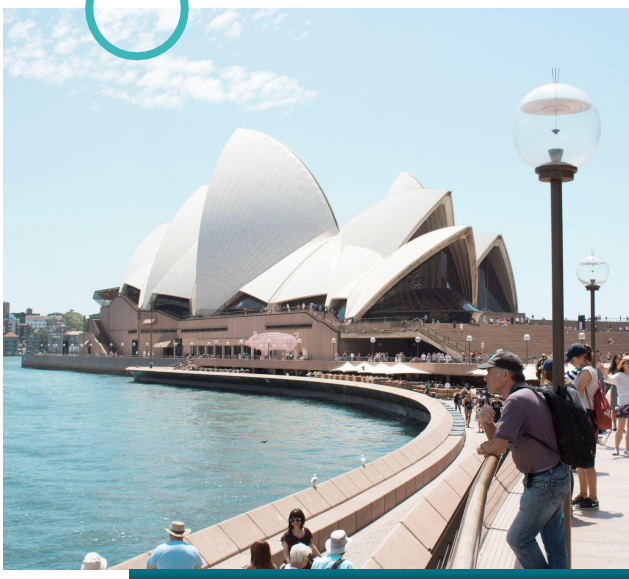


Photo by S O C I A L . C U T on Unsplash

Please visit Consensys for more information on blockchain-based CBDC architectures.

PHASE: RESEARCH

Saudi Arabia and U.A.E.

A CBDC pilot using Hyperledger Fabric completed by the central banks of Saudi Arabia and the United Arab Emirates (U.A.E.) found that distributed ledger technology can improve cross-border transactions and meet the demands of financial privacy in a purely digital context.

In this report on Project Aber, the two central banks outlined the lessons learned from a yearlong proof-of-concept meant to test the viability of a shared digital currency.

This project was one of the first to test cross-border transactions and has been referenced in future projects elsewhere in other jurisdictions.

Please visit IBM for more information on blockchain-based CBDC architectures.

Hyperledger Global Forum

Hyperledger Global Forum is the annual enterprise blockchain event for business and technology leaders.

For the last two years at Hyperledger Global Forum (HGF), those on the front lines of CBDC deployments and the development of critical underlying platforms and technologies presented a mix of talks and workshops about requirements for and challenges of implementing current and future payment solutions.

Keynote Panel: The CBDC Journey: Research, Live Deployments, and Policy Considerations - Nicolas de Labarre, Banque de France; Sarah Palurovic, Digital Euro Association, Mai Santamaria, Dept. of Finance Ireland

Sessions on CBDCs:

- Build CBDC Platform on Hyperledger Besu – Dive in Retail CBDC's Architecture – Charles d'Haussy, ConsenSys
- Hyperledger Iroha: Enabling CBDC and FinTech Use Cases (Bakong CBDC in Cambodia) - Makoto Takemiya, Soramitsu
- Towards a Scalable, Privacy-Preserving, and Regulatable CBDC Framework - Mark Rakhmilevich, Oracle
- Creating a Retail CBDC Prototype With Hyperledger Fabric - Imre Kocsis, Budapest University of Technology and Economics
- Making Distributed Ledgers Interoperable Using Weaver (Hyperledger Labs) - Venkatraman Ramakrishna, IBM
- Workshop: Moving Central Bank Digital Currency from Conception to Reality with Hyperledger Technologies - Elli Androulaki & Angelo De Caro, IBM
- Smart Contracts with Tokenized Fiat Currency on Sberbank's Platform – Oleg Abdrashitov, Sberbank

Read more: CBDCs, programmable money and interoperability – Part I and Part II recap blog post.

Additional Videos & Recordings

Blockchain engineers at Banque de France and IBM, provide a technical presentation and feedback on the Banque de France Venus CBDC experiment and how Hyperledger Fabric addresses many of the requirements for CBDC use cases.

This video shows how Hyperledger Technologies helped build a CBDC, how it was used to orchestrate interoperability with HTLC, and will offer a deep-dive and hands-on session on the Hyperledger Fabric Token SDK lab. Watch it here.

Watch a curated selection of Hyperledger CBDC member webinars, special interest group presentations, global forum keynotes and more here.

Listen to experts at Davos 2022 in government–Central Bank, open source technology development and collaboration share their views on why open source tech and collaboration is the key to accelerating progress on CBDC research, adoption in financial services and in government.

Jim Cunha, senior vice-president, secure payments and fintech of Hyperledger Foundation Member Federal Reserve of Boston, discusses the "Boston Fed's CBDC Project" as well as the wider impact of distributed ledger technology on the financial system.

Governance, standards and interoperability: Getting past the roadblocks to peer-to-peer financial transactions with IBM, Consensys and Soramitsu - discussing the use of Hyperledger technologies in wholesale and retail CBDC projects.

Additional Resources

Workshops

- Making headway – Results of the 2022 BIS survey on central bank digital currencies and crypto
- International Monetary Fund - A guide to Central Bank Digital Currency Product Development
- How should central banks approach Central Bank Digital Currency?
- World Economic Forum - Central Bank Digital Currency Global Interoperability Principles
- CFA Institute Global Survey on Central Bank Digital Currencies
- CBDC Transactions to Exceed $213 Billion by 2030 Globally, as New Payment Models Acceleration Financial Inclusion
- Expanding Financial Inclusion or Deepening the Divide? MIT & the Digital Currency Initiative
- The Federal Reserve Bank of Boston and the Digital Currency Initiative at the Massachusetts Institute of Technology released the findings of Project Hamilton, which describes a theoretical high-performance and resilient transaction processor for a CBDC by developing open-source research software, OpenCBDC.

CBDC Trackers:

  - Atlantic Council CBDC Tracker
  - Kiffmeister Wholesale CBDC Tracker
  - Kiffmeister Retail CBDC Tracker
  - BCG CBDC Tracker
- OMFIF Retail CBDCs: The next payments frontier

Photo by Mark Boss on Unsplash

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Daniela Barbosa serves as General Manager Blockchain, Healthcare and Identity at the Linux Foundation with overall strategic and operational responsibility for staff, programs, expansion and execution of Hyperledger Foundation's mission.

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Karen Ottoni supports the diverse ecosystem of innovative companies implementing enterprise blockchain in various industries. She leads in promoting best practices and examples of how digital assets can improve financial systems.

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Thank You

Join us in our journey to build enterprise blockchain ecosystems through global, open source collaboration.

JOIN US

www.hyperledger.org