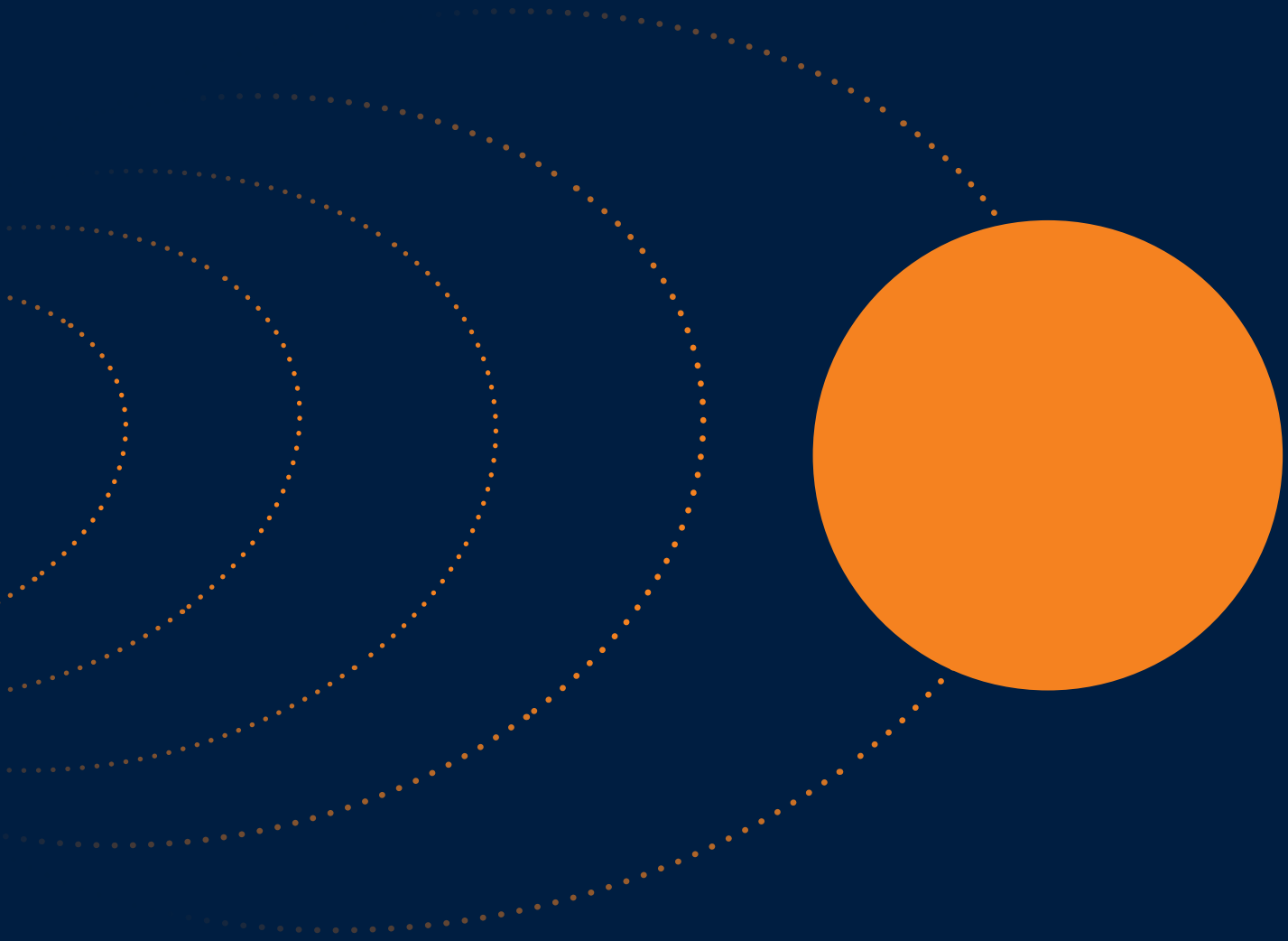
PROJECT VENUS



BANQUE DE FRANCE
EUROSYSTÈME

BANQUE CENTRALE DU LUXEMBOURG
EUROSYSTÈME

European Investment Bank

Goldman Sachs

SOCIETE GENERALE

Santander

Contents

Executive summary

Project Venus successfully demonstrated the legal, technical and operational feasibility of a digital bond issuance by the European Investment Bank (EIB), for the sum of EUR 100 million underwritten by Goldman Sachs, Société Générale, and Santander, for which the settlement took place via an experimental wholesale CBDC, represented as tokenised form of euro central bank money (CeBM).

The transactions took place in two steps: the first consisting of a primary market Delivery vs. Payment (DvP) settlement between the EIB and Goldman Sachs acting as lead bank, and subsequently, settlements between Goldman Sachs and the primary market investors of Société Générale, Santander and Goldman Sachs.

The digital bond issuance and cash settlement were conducted using two different Distributed ledger technologies (DLTs): the Securities DLT provided by Goldman Sachs, and the cash DLT provided by the Banque de France in co-operation with the Banque centrale du Luxembourg (Central Bank of Luxembourg), for the provision of the experimental wholesale CBDC in euro. The interoperability using the DLTs was achieved via a Hashed Timelock Contract (HTLC) mechanism, enabling T0 settlements to be realised atomically in the primary market.

Key takeaways:

No.1:
Wholesale CBDC is a safe and efficient solution for the settlement of tokenised assets.

No.2:
Wholesale CBDC speeds up the issuance process, achieving a T0 settlement cycle.

No.3:
The HTLC mechanism facilitates and secures the interoperability between DLTs, enabling an atomic settlement.

No.4:
Technical solutions exist to facilitate the interactions with the entities that do not have access to central bank money and infrastructures.

No.5:
Wholesale CBDC can interoperate with various DLTs and hence could accompany and secure the development of tokenisation.

No.6:
Further cooperation and exploratory work is needed at Eurosystem level, before issuing a wholesale CBDC.

Introduction

On 29 November 2022, the European Investment Bank (EIB) successfully issued its first euro-denominated digital bond on a private blockchain using central bank money (CeBM) in the form of an experimental wholesale central bank digital currency (CBDC) for settlement, under the name Project Venus. This project follows the first digital bond issued by the EIB in 2021 on a public blockchain using an experimental wholesale CBDC.[1]

The project brought together two Eurosystem National Central Banks, acting as buy-side, and sell-side actors to establish a DLT based capital market ecosystem. The Banque de France (BdF) and the Banque centrale du Luxembourg (BCL) provided CeBM as a settlement asset in the form of an experimental CBDC, via a tokenised representation of euro CeBM, to settle a EUR 100 million EIB digital native bond. EIB appointed three syndicate banks, Goldman Sachs Bank Europe (GSBE), Santander (SAN) and Société Générale (SG), to facilitate the subscription and distribution of the digital bonds.

The EIB digital native bonds were issued and registered on a private permissioned DLT operated by GSBE, named GS DAPTM (the Securities DLT) and CBDC tokens were issued and distributed on a separate and independent private permissioned DLT, named DL3S (the cash DLT), jointly operated by the BdF and the BCL. The delivery of EIB digital bonds settled in CBDC, via the deployment of a message exchange mechanism between the two DLTs – Hashed Timelock Contract (HTLC) protocol. HTLC allowed a Delivery versus payment (DvP) settlement via an atomic settlement, where the EIB's digital bonds were delivered to the lead bank in exchange for CBDC. The lead bank was then able to onward deliver to investors on the same day of the issuance (i.e. T0). Due to the absence of legal tender for euro CBDC, all cash legs on the cash DLT were pre-funded and withdrawn via TARGET2 accounts.

Due to complexities and limitations of holding CBDC overnight and for the full duration of the bonds, for the scope of Project Venus, experimental CBDC tokens were only made available intraday for the primary market issuance and settlement.[2] Therefore, in the event of secondary trading, lifecycle events such as coupon payments and the final redemption of the digital bonds, traditional CeBM payment would be leveraged for the cash leg of such events. This paper has been written with these limitations in mind and particularly focusing on the primary market issuance and settlement leg of the transaction.

From a legal and regulatory perspective, Project Venus digital bonds were issued as dematerialised securities in accordance with the Luxembourg act dated 6 April 2013 on dematerialised securities (the Dematerialised Securities Act 2013). The bonds have the legal status of financial instruments under MiFID II (Markets in Financial Instruments Directive II).

In accordance with the Dematerialised Securities Act 2013, the digital bonds were:

1. initially recorded in a securities issuance account kept on the GS DAP™ operated by GSBE, acting via its Frankfurt head office as Central Account Keeper (**CAK**)

2. kept in securities accounts at the top-tier level by GSBE as account keeper (**AK**), and

3. subsequently transferred via book-entry between top-tier securities accounts operated by GSBE on the GS DAP™.

1 Referred to as CBDC elsewhere in the text for ease of reading.

2 An intraday CBDC means that there is a mandatory conversion of the CBDC into reserve balances before the value date change in TARGET2.

The securities issuance account and the top-tier securities accounts were all held on the GS DAP™ operated by GSBE in Germany.

This paper presents Project Venus starting with the overview of the stakeholders and the explanation of the Project Venus concept in Parts 2 and 3, while Part 4 deep-dives into the business flows. Parts 5, 6 and 7 address the cash DLT infrastructure, the securities DLT infrastructure and the HLTC communication between these two DLTs. Part 8 focuses on the technical aspects of the overall model. Finally, Part 9 concludes on the findings of this project.

Definitions

Atomic settlement: a settlement that is both simultaneous and instant.

Bond pricing: refers to the process that is used to calculate the prices of bonds sold in the primary or secondary market.

Book building: the process of creating a primary market order book by capturing investor orders.

Cash DLT: refers to the infrastructure on which the tokenised settlement assets are issued and circulate.

Central bank digital currency (CBDC): here an experimental tokenised form of central bank money.

Central account keeper: investment firm or credit institution in charge of maintaining a register, in accordance with the Dematerialised Securities Act 2013.

Delivery versus payment (DvP): a form of securities settlement involving the simultaneous delivery of securities against payment.

Dematerialised Securities Act 2013: the Luxembourg act dated 6 April 2013 on dematerialised securities, as amended.

Distribution to investors: Primary market settlement under which the lead bank coordinates delivery to investors.

DL3S: the Cash DLT provided by the Banque de France.

Distributed ledger technology (DLT): refers to the protocols and supporting infrastructure that allow computers in different locations to propose and validate transactions and update records in a synchronised way across a network.

Free of payment (FOP): refers to the delivery of securities with no corresponding payment.

DAP: a Security DLT provided by Goldman Sachs.

Hashed-Timelock-Contract (HTLC): a protocol that allows for the interoperability between two DLTs without third party intermediation.

Joint-lead-manager (JLM): the bank entities appointed by the issuer of the digital bonds forming a syndicate to underwrite the transaction.

Lead bank: the JLM which receives the digital bonds from the issuer and is responsible for distribution to investors.

National central bank (NCB): a Eurosystem central bank other than the European Central Bank.

Payment bank: a commercial bank acting as a cash correspondent bank.

Primary market: market where securities are sold to investors by issuers for the first time.

Secondary market: market where investors sell and buy securities.

Securities custodian: a financial institution that provides securities custody services.

Securities issuance account: the Issuer's *compte d'émission* or securities issuance account, as required by the Dematerialised Securities Act 2013, maintained on GS DAP in the form of a wallet, that will be used to indicate elements relating to the identification of the digital bonds, the quantity issued and any subsequent changes to the record of the digital bonds kept by GSBE acting as central account keeper.

Security DLT: refers to the infrastructure on which the tokenised securities are issued and circulate.

Syndication: refers to the action of several banking partners grouped together to provide funds for a financial transaction.

Takedown from issuer: Primary market DvP settlement leg of the digital bonds between the Issuer and the lead bank.

TARGET2: the Eurosystem real-time gross settlement (RTGS) system from November 2007 to March 2023.

TARGET2 escrow account: account held by central banks and used for the prefunding of CBDC token.

TARGET2 participant: participant in the Eurosystem RTGS system.

The stakeholders

Project Venus encompasses the following stakeholders playing different roles.

BANQUE DE FRANCE EUROSYSTÈME	Experimental central bank digital currency provider Cash DLT platform provider Cash DLT platform operator TARGET2 escrow account owner
BANQUE CENTRALE DU LUXEMBOURG EUROSYSTEM	Experimental central bank digital currency provider Cash DLT platform operator TARGET2 escrow account owner
European Investment Bank	Digital native bond issuer TARGET2 participant
Goldman Sachs	Joint-lead-manager (JLM) Lead bank Central account keeper / registrar Security DLT operator / Securities custodian Payment bank TARGET2 participant Investor
SG	Joint-lead-manager / Securities custodian Payment bank TARGET2 participant Investor
Santander	Joint-lead-manager Investor
Investors	Investors (unknown)

1. Project Venus overview – Digital bond issuance

Capital markets have evolved over time embracing the latest technologies. The advancement of computing power in the 1970s paved the way to the electronification of markets, where trading shifted from voice and paper based open-outcry trading to request for quote (RFQ) and central limit order book (CLOB) based automated exchange trading. This technological evolution has predominantly occurred in the pre-trade and execution layers of the value chain.

However, over the last 10 years, DLTs have emerged as a potential viable technological solution to streamline post-trade processes in capital markets.

DLT offers a wide range of benefits for the financial industry. The inherent distributed nature of the network, traceability, and immutability of the data have the potential to streamline the value chain and reduce cost and post-trade risks.

The European Investment Bank, as an issuer, began its digital assets journey issuing its first ever digital bond leveraging Ethereum, a public permissionless DLT, in April 2021. Since then, the EIB explored further digital bond issuance leveraging DLTs across different markets and technical configurations. This paper focuses on Project Venus, which is a EUR 100 million EIB digital bond issuance, in partnership with two Eurosystem central banks: the Banque centrale de Luxembourg and the Banque de France, which explore DLT applications for a wholesale central bank money solution and investigate its interoperability models.

The overall operating model selected for Project Venus consisted of a Cash DLT (DL3S) inter-connected with a Security DLT (GS DAP). Both DLTs are private permissioned networks and are managed independently by the BdF and GSBE, respectively. The setup aimed to model a potential realistic future environment, where multiple DLTs may coexist in parallel and will likely be required to interoperate to facilitate capital markets activity in a digital ecosystem. The interaction and communication between the two DLTs were facilitated via the HTLC mechanism. HTLCs first emerged in 2015 as an interoperability solution in the crypto industry for public-permissionless blockchains. The main objective of HTLC is to reduce counterparty risk by enabling a time and hash-based escrow that requires a cryptographic key for the lock and release of smart contracts. In Project Venus, this technology was successfully applied to demonstrate interoperability between two private permissioned DLTs, which facilitated a digital bond issuance and atomic settlement in the primary market.

2. Venus issuance business flows

The overall digital bond issuance and settlement process can be summarised into the steps outlined in the table below.

	#	STEPS	ON/OFF-CHAIN	SYSTEM	DESCRIPTION
ISSUE DATE – 1	1	Book building	Off-chain	IssueNet	Capturing of primary market investor orders by the joint-lead-managers (JLMs)
	2	TARGET2 instruction		TARGET2	Liquidity transfer instructed by JLMs into central bank TARGET2 escrow account on issue date – 1, to be settled on issue date
ISSUE DATE & SETTLEMENT DATE (T0)	3	TARGET2 settlement	Off-chain	TARGET2	TARGET2 liquidity transfer settlement on issue date
	4	CBDC issuance	On-Chain	DL3S	Creation of CBDC token in cash DLT
	5	Bond pricing	Off-Chain	Bloomberg	Pricing of bond in market
	6	Investor / JLM CBDC allocation	On-Chain	DL3S	Allocation of CBDC token by payment bank in cash DLT
	7	Issuance		GS DAP	Creation of bond token in security DLT
	8a	DvP 1 – Takedown: DvP settlement between the lead bank and the issuer		DL3S / GS DAP	Primary market issuance settlement between the issuer and the lead bank
	8b	DvP 2 – Allocation: DvP settlement between the lead bank and the investors		DL3S / GS DAP	Primary market settlement between the lead band and the investors (via security custodian)
	9	CBDC redemption +TARGET2 settlement	On & Off-Chain	DL3S TARGET2	Destruction of CBDC token by issuer and payment bank, post TARGET2 settlement

Prior to the book building process, similar to traditional market issuance, the joint-lead-managers (JLMs) marketed the bond to potential investors via roadshows over a period of a month prior to the issue date. Once the marketing period was complete, subject to market conditions, the issuer and the JLMs targeted an issue date.

The day before the issuance, similar to traditional market issuance, two steps were performed: (i) the book building; and (ii) the liquidity transfers in TARGET2. **The book building** process aims to capture primary market client orders. This took place off-chain using the traditional market participants' processes a day prior to the issue date. An important point to highlight is that at this stage, the bond is yet to be priced in the market. Capturing investors' orders a day prior to issuance enables the JLMs to establish the end allocation required for the primary market settlement of the digital bonds. **The TARGET2 settlements** were scheduled in parallel to the book building process. The payment banks (GSBE and SG) scheduled a liquidity transfer in TARGET2 on the day prior to the issuance/settlement date (T-1) to fund an escrow account jointly owned by both the Banque de France and the Banque centrale de Luxembourg, on **issue date**, for the full notional par value of the digital bonds – EUR 100 million. The funding of the central bank escrow account allows for the issuance and distribution of CBDC tokens.

On the issuance date (Settlement Date T0), unlike traditional market issuance, several processes took place, starting with the **CBDC Issuance**. At TARGET2 opening (7am CET), the liquidity transfer instructed on issue date – 1 settled into the central bank escrow account. Central banks then proceeded to mint equivalent amount of CBDC tokens and deposited them into payment bank's wallet in the central banks cash DLT Platform. Thus, the amount of CBDC tokens minted is 1-for-1 backed by the CeBM deposited into the central bank escrow account in TARGET2.

The **bond pricing** was carried out at market opening (8am CET), based on the reference rate and spread, agreed by the issuer and the JLMs. Once priced, all final cashflows were known which enabled the relevant JLMs to request payment from investors, based on their end-allocations. Investors do not have direct access to central bank money, hence, to buy the bonds, but must prepay via a payment bank. In this case, both GSBE and SG acted as payment banks.

The **investor/JLMs CBDC allocation** occurred at 8:30am CET, once CBDC tokens were deposited into the payment bank wallet in step 4 above and final cashflows were determined post pricing in step 5. The payment bank allocated the CBDC tokens in DL3S into respective main-wallets and sub-wallets depending on the scenarios, in preparation for the primary market DvP settlements:

- Main wallet: a cash wallet under the name of the payment bank, used to represent CBDC held on behalf of the JLMs.

- Sub wallet: a cash wallet under the name of the payment bank, used for operational purposes to assist with allocation to investors.

The **issuance** took place at around 9.30am CET, with the creation of the security token smart contract on the GS DAP prior to primary market issuance and settlement. GSBE, acting as the central account keeper, recorded the characteristics of the bond into its securities issuance account. A bond token was recorded in an issuer notional account for the technical purpose of facilitating settlement – at this stage the bond token does not represent a security in its legal sense.

From this point, the primary market settlement took place in two distinct atomic delivery versus payments operations (DvPs): **takedown from issuer** and then **distribution to investors**.

Concerning the **takedown from issuer**, GSBE, as the lead bank subscribed the entire issuance amount, leveraging the trustless HTLC cross-chain DvP execution. This atomic and cross chain DvP used the trustless HTLC protocol and resulted in a simultaneous:

- CBDC token transfer from the lead bank's cash wallet to the issuer's cash wallet, on the cash DLT (DL3S) and,

- Bond token transfer from the issuer notional account to the lead bank's account, on the security DLT (GS DAP). At this stage, the lead bank owned the entire outstanding amount of the digital bonds, and the issuer owned the corresponding amount in CBDC.

Concerning the **distribution to investors**, the lead bank distributed the digital bonds based on primary market allocation captured during the book building process (step 1), leveraging the trustless HTLC cross-chain DvP execution from the perspective of TARGET2 participants. This atomic DvP operation resulted in a simultaneous:

- CBDC token transfers from the investors sub-wallet to the lead banks' wallet, on the cash DLT (DL3S) and,

- A bond token transfer from the lead bank's account into the securities custodian's account, on the securities DLT (GS DAP).

Note that the investor had no legal rights over the CBDC tokens.

The **CBDC redemption (or burning)** was the last step, followed by a **TARGET2 liquidity transfer**. The CBDC redemption (or burning) process was performed by the central banks on the payment bank's request. When CBDC tokens were redeemed, a TARGET2 liquidity transfer was manually instructed for an equal amount. This flowed from the NCB's escrow account to the payment bank's TARGET2 account (falling under the same NCB jurisdiction):

- The issuer instructed CBDC burning directly after the takedown from issuer – Step 8a(i);
- Once the digital bond was fully allocated to investors through the completion of the distribution trades – Step 8b(i).

The main factor explaining the intra-day nature of the CBDC redemption is the lack of legal qualification, as the CBDC is not classified as legal tender. It could not therefore not be held overnight, and and payment finality took place in the TARGET2 environment.

One key success of Project Venus was its ability to compress **primary market settlement from an average range of T+2 to T+5 settlement into a T0 atomic settlement**, with each DvP (8a and 8b) taking less than 60 seconds to complete. This compressed settlement cycle carries significant benefits for capital markets, as it reduces intra-settlement counterparty credit risk, eliminates settlement failures thanks to atomicity and therefore ultimately improves post-trade efficiency and cost.

CBDC tokens were only made available for primary market settlement. In cases any secondary trading, free of payment (FOP) settlement was managed between Investors and the JLMs in TARGET2 for the cash leg and GS DAP for the security leg.

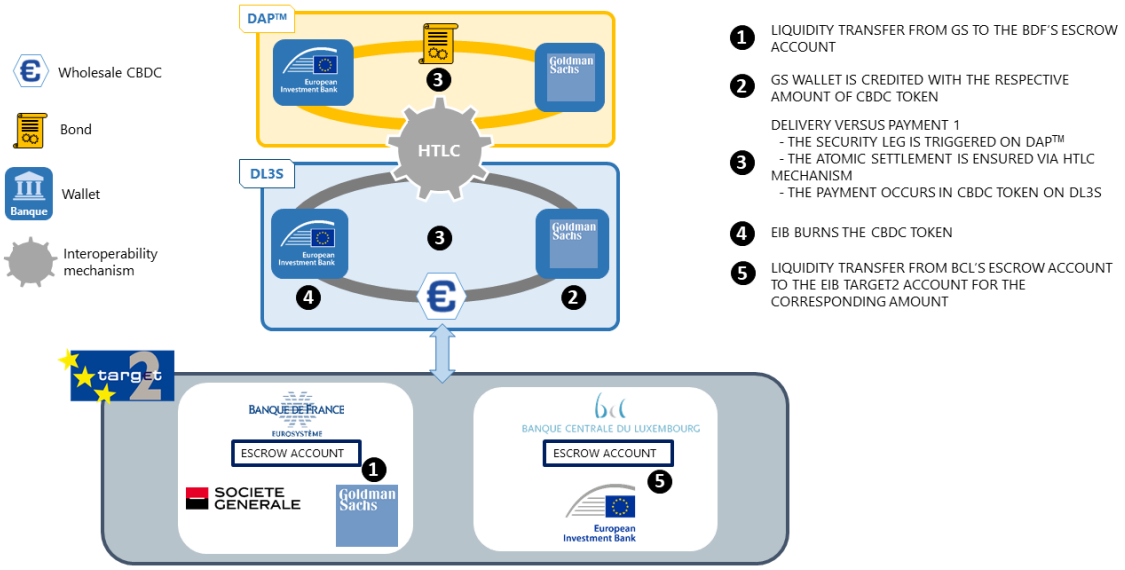


ILLUSTRATION DvP 1 – The subscription between the issuer (EIB) and the lead bank Goldman Sachs (GS)

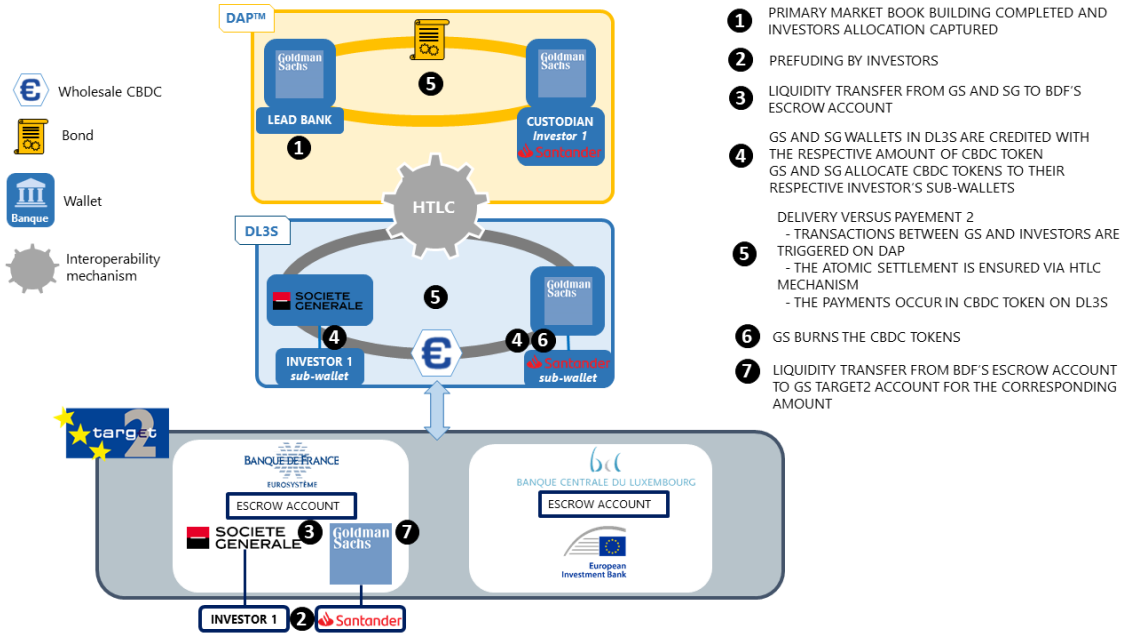


ILLUSTRATION DvP 2 – The digital bond allocation between the lead bank (GS) and the other bank syndicates and investors The subscription between the issuer (EIB) and the lead bank Goldman Sachs (GS)

3. The Cash DLT: DL3S

The Banque de France and the Banque centrale du Luxembourg jointly operated the cash DLT, a permissioned network where both National Central Banks (NCBs) issued and distributed the CBDC to Cash DLT custodians. As DLT operators, the Banque de France and the Banque centrale du Luxembourg (i) managed the overall configuration of the network with the establishment or removal of DL3S participants, i.e. granted DL3S access to payment banks via the creation of nodes and wallets; and (ii) monitored the interoperability components with the security DLT. Payment banks relied on their NCB as an entry point for all TARGET transactions. Each central bank has access only to the transactions of its TARGET2 participants. The cash DLT, i.e., DL3S, was interoperated with the security DLT, i.e., GS DAP, and allowed for full control over the CBDC and its ecosystem, while maintaining the capacity to interact with one or more security DLTs with their specific technologies and business models.

The network infrastructure used for the Venus experiment is underpinned by the following key features:

- Permissioned distributed ledger platform based on Hyperledger Fabric;
- High level of privacy and capacity to segregate data confidentiality based on actors' defined roles and responsibilities while maintaining adequate performance;
- Cash settlement execution according to a trustless HTLC mechanisms;
- Modular with specific components such as the Unspent Transaction Output (UTXO) model or interoperability connectors.

Each participant had the ability to interact with the cash DLT according to roles and responsibilities. The two NCBs defined the overall membership structure. They managed the technical business flows in partnership with Goldman Sachs to ensure a consistent setup between the two networks.

3.1 Central banks

Both NCBs operating the cash DLT network were in charge of issuing, distributing and redeeming CBDC. They also supervised the overall DLT activity, which meant having access to the overall wallets and sub-wallets balances of payment banks and the transactions of the cash DLT participating members. NCBs also ensured that the Venus experiment was conducted within the appropriate regulatory framework. In particular, in the absence of qualification for the CBDC tokens used, the finality of the cash settlement was ensured in TARGET2 and the finality of the security leg was ensured contractually.

Each NCB managed the payment banks in its own jurisdiction. NCBs hold an escrow account in TARGET2 that payment banks can credit, from their TARGET2 account to request CBDC token creation on the cash DLT. NCBs granted access to the cash DLT to payment banks: each NCB could authorise the payment bank on the cash DLT (equivalent to whitelisting, i.e. granting network access to the cash DLT participant). Operationally this was reflected as granting a node and wallets to the payment bank. NCBs had the same rights and capacity to interact with the cash DLT as any other payment bank (holding CBDC and performing transactions). NCBs consulted, for their own jurisdictions, the balances and transaction histories of payment banks' wallets.

The Banque de France was the technical provider of the cash DLT platform. It provided the DL3S platform and the interoperability mechanism between DL3S and DAP, in coordination with Goldman Sachs, to ensure trustless DvP executions. The Banque de France also hosted DL3S participants' node to facilitate the implementation of the Project Venus.

3.2 Payment banks

The payment banks were connected TARGET2 participants. Once authorised by an NCB, the payment bank was granted a cash wallet that could be accessed through the attribution of a node granted to the participant or through the node of another blockchain participant. Each security custodian had to define a payment bank representing its overall business interests on the cash DLT. In this key role, the payment bank manages the overall cash operations for itself and third parties. In the context of the Venus Project, the role of the payment bank encompasses two types of action: **static data management** and **liquidity management** for itself and its clients (i.e. the investors).

The static data management consists in creating, monitoring and amending wallets for its investors and for itself. Payment banks must also hold the private keys of notional sub-wallets.

Payment banks can **manage their liquidity** using a single wallet on DL3S. The CBDC is minted following a cash transfer executed in TARGET2, namely from the payment bank's TARGET2 account to the NCB escrow account. The payment banks can then execute a liquidity transfer (or CBDC transfer) between their own wallets. They execute the cash leg of DvP transactions triggered on GS DAP. They hold CBDC for their own account or on clients' wallets. CBDC is redeemed following the triggering of a cash payment from the NCB escrow account to the payment bank's TARGET2 account.

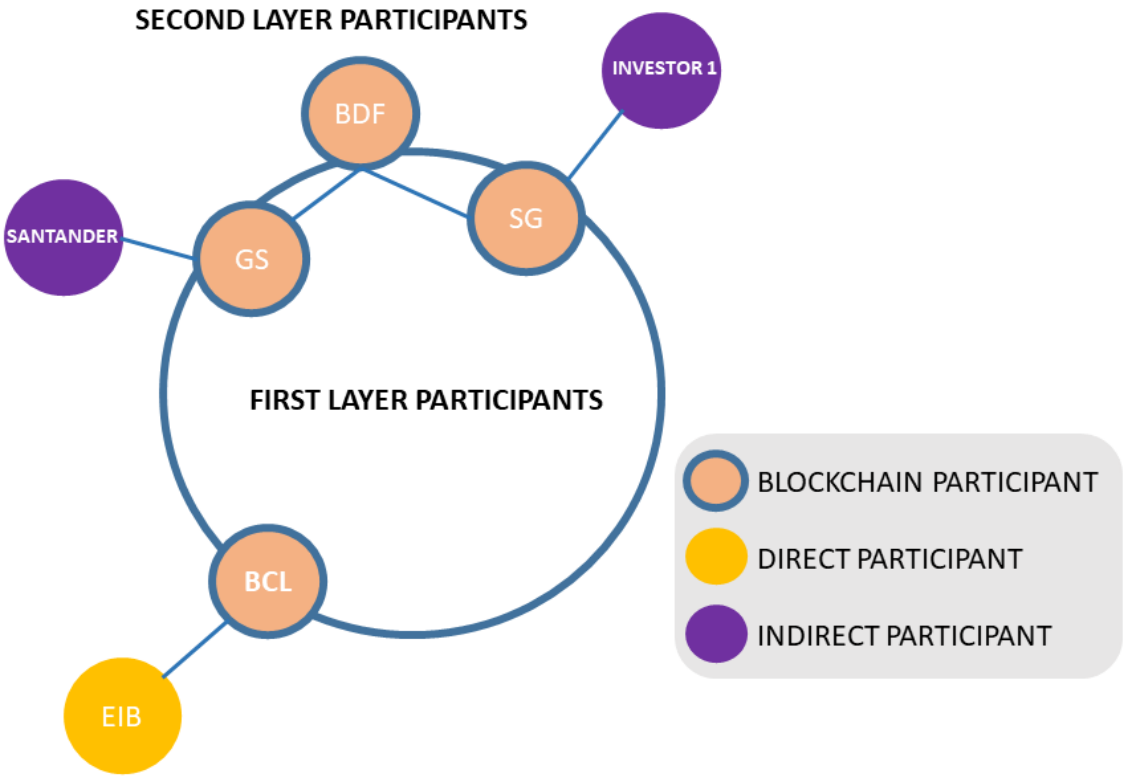
3.3 Investors

Final investors (non-banks, including investment funds) cannot hold an account in TARGET2, following the Eurosystem policy, and the payment banks remain the final holder of the CBDC credited in each investor sub-wallet, i.e. sub wallets belong to payment banks.

Investors may only be granted read-only access to the cash DLT to be able to see the balance of the sub-wallet which their payment bank used for operational purposes (for this transaction, the investors had no rights or interests in such sub-wallets). Any action related to payment execution is performed by the payment bank. The client read-only access encompasses cash balances and overall payments transactions theoretically corresponding to market executions such as DvPs, coupon distribution, redemption or any market event triggered by the securities DLT.

The client access rights (logins and cryptographic access) are provided by the payment bank. With this sub-wallet service, NCBs aimed to allow payment banks to segregate the cash positions and operations at investor level.

3.4 DL3S participation scheme



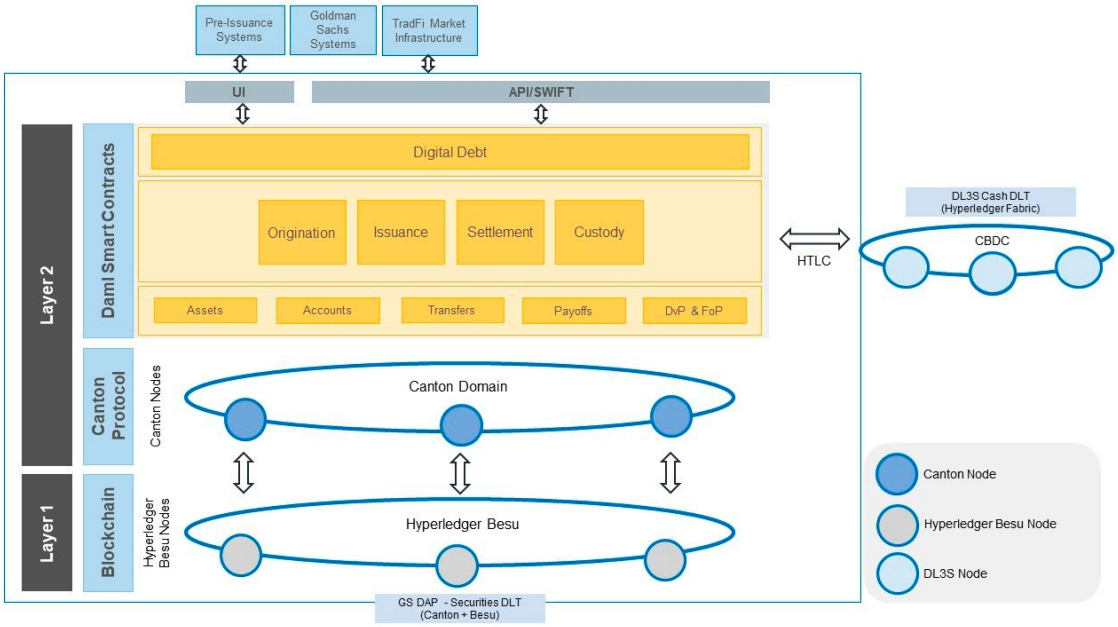
BLOCKCHAIN PARTICIPANT	DIRECT PARTICIPANT	INDIRECT PARTICIPANT
▪ A blockchain participant has a node of the network, hence has access to the network ledger.	▪ Direct participants do not have a node of the network. ▪ They are participant to DL3S connected through the node of a blockchain participant. ▪ Direct participants can interact with the network e.g. send requests, access accounts balances, etc.	▪ Indirect participants cannot access the network in any way. ▪ Blockchain participants or direct participants may provide them read-only access to the network.

4. The Securities DLT: GS DAP

4.1 DLT Presentation

The GS DAP is an end-to-end tokenisation and life cycle management solution for digital assets, that is designed and built by Goldman Sachs. The platform has two distinct technical layers:

- Layer 2 – application layer, houses the business logics using the open source Daml smart contract via Canton nodes;
- Layer 1 – DLT layer, runs the private permissioned DLT Hyperledger Besu, which acts as a messaging bus connecting Canton nodes.



The two-layer design offers flexibility, futureproofing for enhancement and interoperabilitywith potentially different layer 1 DLT networks. The GS DAP also integrates with traditional finance systems such as pre-issuance book building tools, back office operation systems and the SWIFT messaging protocol.

In the context of Project Venus, the GS DAP represented the security DLT platform where the EIB digital bonds were originated and issued via Daml smart contracts. The experimental CBDC tokens were solely represented on the central bank DL3S platform jointly operated by the Banque de France and the Banque centrale de Luxembourg. Therefore, in order to synchronise/interoperate the two DLT networks for DvP transactions, a Hashed-Timelock-Contract mechanism was deployed – see section 9 for further details.

The representation of assets, accounts, transaction data and any other business events or states were captured using purpose-built Daml smart contracts on the GS DAP. Canton Domain protocol in layer 2 was used to synchronise shared smart contracts across Canton nodes. The Besu nodes in layer 1 received encrypted payloads from the layer 2 Canton nodes and performed Ethereum protocol validation, for the purpose of achieving consensus in terms of the ordering of transactions and supporting inter-node communication.

4.2 Custody on DAP

While the legal status of the EIB bonds was MiFID II transferable securities, from a technical perspective the custody of digital assets is more complex. The model chosen required GSBE to act as a custodian in respect of the bonds, and any other custodian wishing to hold the digital bonds for its clients would need to appoint GSBE as its sub-custodian. Due to the lead time for a custodian to develop such a relationship, few custodians met these requirements, limiting the ability for investors to access the digital bond. Several possible solutions could improve asset liquidity and reduce this market fragmentation, such as onboarding more participants on market DLTs, ensuring connectivity between market DLTs, applying for additional licences (DLT Pilot regime, central security depository) to accept assets for trading, covering regulated markets, multilateral or organised trading facilities.

5. Hashed-Timelock-Contract Trustless interoperability protocol between DLTs

In an environment where both the asset and the cash tokens exist on the same blockchain/DLT, truly atomic settlement can be achieved, given that the single chain offers native interoperability and a common consensus mechanism. Smart contracts on this single chain can be written to ensure that neither leg of the trade is executed unless both sides agree, and both sets of tokens are available.

However, the operational setup for Project Venus combined a Cash DLT platform operated by the Banque de France/the Banque centrale du Luxembourg and a separate security DLT platform operated by GSBE. Therefore HTLCs were implemented to coordinate DvP settlements across the two DLTs.

HTLCs are specific type of smart contract that are used to facilitate transactions between parties across DLTs, in a secure and trustless way by ensuring that certain conditions are met before transactions are completed.

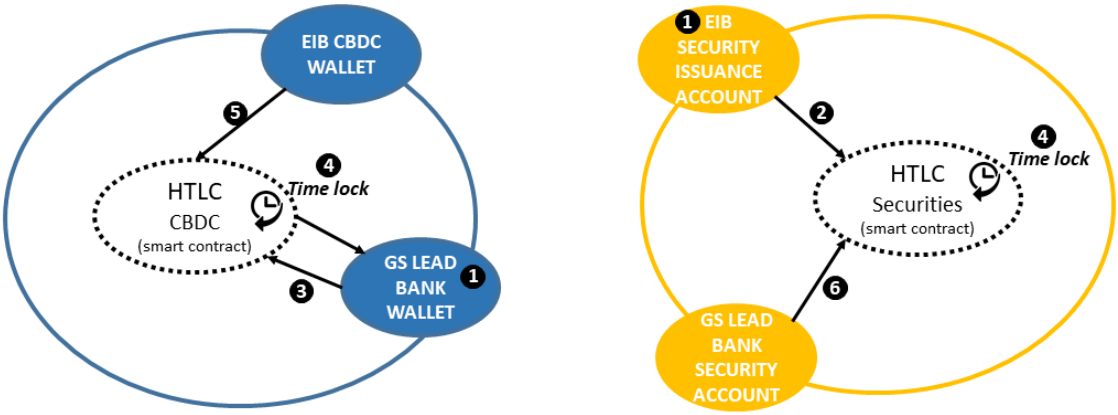
In Project Venus, HTLC smart contracts were deployed to facilitate the swap of bond and CBDC tokens, using the GS DAP operated by GSBE and DL3S, operated by the Banque de France/the Banque centrale du Luxembourg. HTLCs acted as an interoperability solution which employed a hash and time-based locking and release mechanism, that was enabled via cryptographic keys/signatures.

The DvP conducted in Project Venus used a trustless mechanism to interoperate the cash DLT with the security DLT. To provide interconnectivity capabilities (data transfer, asset transfer, asset exchange), DL3S implemented application and communication layer constructs, including the Hashed Timelock Contract (HTLC). HTLCs are time-bound conditional payments cross networks that do not require a trusted third party.

The HTLC protocol allowed buyers and sellers to perform an – exclusively DLT-based – cross-platform asset exchange without needing any intermediation, provided they all participated in both platforms. To do so, the HTLC locked the assets for the opposite party, and a secret and its hash are exchanged, according to a precise protocol, guaranteeing that at the end of the DvP both assets change hands or neither does.

To perform the DvP settlement, the HTLC mechanism works on three trust assumptions:

- The DL3S DLT trusts the securities DLT as responsible for the DvP validation and matching processes.
- The seller's securities custodian and the seller's payment bank know and trust each other in their relationship regarding the seller.
- The buyer's securities custodian and the buyer's payment bank know and trust each other in their relationship regarding the buyer.



Steps of a DVP settlement process based on HTLC under Project Venus (DvP 1):

1) EIB and GSBE (Lead Bank) agree to the following takedown trade:
   - *EIB sells **100 million of EIB bonds** represented on GS DAP to GSBE (as lead bank), for a total of **100 million EUR CBDC tokens** represented on DL3S.*

2) EIB generates a secret (X) and hash (Y), which is used to create a HTLC(1) on GS DAP that locks the bond tokens in a smart contract, with a time limit and a hash function. Instructions contained in the HTLC:
   - *Send **100 million of EIB bonds** to GSBE (lead bank), once GSBE provide the secret **X** that results in hash **Y**, once passed through hash function **F**. If secret X isn't provided within **60 minutes**, return the bonds to EIB.*

3) GSBE (lead bank) sees the details of EIB's HTLC, which GSBE (lead bank) uses to create a corresponding HTLC(2) on DL3S. Instructions contained in the HTLC:
   - *Send **100 million of CBDC tokens** to EIB once EIB provides secret **X** that results in hash **Y**, once passed through the same hash function **F**. If secret X isn't provided within **30 minutes**, return the CBDC tokens to GSBE.*

4) At this point the bond tokens are locked for 60 minutes and the CBDC tokens are locked for 30 minutes, and only the EIB possesses the key to unlock them both.

5) EIB uses the secret to unlock the CBDC tokens, which reveals the secret:
   - *DL3S Unlock HTLC(2) = 100 million EUR of CBDC tokens to EIB using Secret X.*

6) GSBE (lead bank) sees this secret and uses it to unlock the bonds.
   - *GS DAP Unlock HTLC(1) = 100 million EUR of EIB bonds to GSBE (lead bank) using Secret X.*
   - HTLC is completed and the trade is settled.

Conclusion

Project Venus successfully demonstrated how **DLTs can serve for primary market digital bond issuance and settlement**. On the one hand, participating central banks provided an exploratory wholesale central bank digital currency (wCBDC) on a private permissioned DLT platform, DL3S. On the other hand, Goldman Sachs provided a separate private permissioned DLT, GS DAP, to manage the digital bonds. The interactions between the two DLTs mimicked a potential future environment where multiple market DLT platforms coexist and access wholesale central bank money (CeBM) via a safe and efficient interoperability model.

The Venus project involved a **"real" DvP transaction**. The asset leg of the Venus transaction experienced a digital native bond issuance[3], while the cash leg of the Venus DvP leveraged exploratory cash tokens available on DL3S, the settlement finality occurring in TARGET2.

Key takeaway No.1:
Wholesale CBDC is a safe and efficient solution for the settlement of tokenised assets.

The use of a tokenised representation of Euro CeBM provided trust by **eliminating credit, counterparty and market risks** that are inherent to other forms of tokenised settlement assets, such as stablecoins. Project Venus demonstrated that a wholesale CBDC underpinned by DLT technology is a viable option to **improve resilience and security** in digital capital markets.

Key takeway No.2:
Wholesale CBDC speeds up the issuance process, achieving a T0 settlement cycle.

In traditional markets, the issuance process, from book building to pricing, issuance, and settlement can take up to T+5 (and not less than T+2). During Project Venus, the primary market DVP settlement took **less than 60 seconds to complete**. All issuance tasks (pricing, issuance, settlement) took place on the same day, achieving a **T0 on-chain settlement cycle** (book building and pre-funding, which took place off-chain, happened at T-1 during the trade phase). T0 appears to maximise settlement efficiency, reduce counterparty risk and free up additional liquidity, although new operational challenges may remain for transition and scalability.

Key takeway No.3:
The HTLC mechanism facilitates and secures the interoperability between DLTs, enabling atomic settlement.

The shortening of the settlement cycle was enabled by the ad hoc Venus **HTLC mechanism**. This mechanism proved the possibility to securely interconnect two DLTs, offering an atomic settlement, simultaneously and instantly on both the cash and securities DLTs, without the need to have securities and cash accounts on the same platform.

DL3S could furthermore support multiple connections with different market DLTs, ensuring a **level playing field** in the provision of central bank money to any eligible market DLT operator.

3 Under Luxembourg blockchain law.

Key takeaway No.4:
Technical solutions exist to facilitate the interactions with the entities that do not have access to central bank money and infrastructures.

At present, the digital form of **wholesale central bank money is only accessible to financial institutions holding a cash account in TARGET services**. The "non-bank" financial actors, including investment funds or corporates, have no direct access to central bank money, as they cannot hold a TARGET cash account.

The Venus experiment removed this limitation by allowing credit institutions to **open sub-wallets in DLS3** to segregate their investors' liquidity, as in direct holding models, except that investors had no direct rights on these sub-wallets. This DL3S sub-wallet feature allowed the maintenance of a consistent mapping between the accounts on DL3S and the accounts on GS DAP. This interesting feature required nevertheless some additional operational requirements for participants and could create liquidity traps, as pre-funding of the sub-wallets is required.

Complementary options could be explored in future experimentation to facilitate the interactions with non-bank issuers and investors. Among these options, links could be developed between wholesale CDBC and tokenised commercial bank money (CoBM), for instance in the form of "**tokenised deposits**", where banks would use wholesale CBDC and investors tokenised deposits.

Key takeaway No.5:
Wholesale CBDC can interoperate with various DLTs and hence could accompany and secure the development of tokenisation.

The Venus project implemented an **interoperability model** combining a cash leg provided by DL3S, in the form of wholesale CBDC, and GS DAP, a securities DLT. Consistent with the level playing field principle, any other eligible market DLT could be allowed to connect and interoperate with the wholesale CBDC. Given that the tokenisation of financial markets is still in its early stages, such a model could be a temporary and pragmatic solution in the short term so as to preserve settlement in central bank money, while allowing financial market players to explore various technologies and platforms for the digitalisation of assets. In this new digital ecosystem, wholesale CBDC can continue to provide the cornerstone of trust by ensuring settlement finality, while meeting the market's need for a secure tokenised settlement asset. The emergence of this new digital ecosystem will also require mechanisms to facilitate links between securities DLTs without fragmentation, thus enhancing the functioning of secondary markets.

Key takeaway No.6:
Further cooperation and exploratory work is needed at Eurosystem level, before issuing a wholesale CBDC.

The Venus project was the first successful tokenised EIB bond issued on a private DLT, listed in a stock exchange and settled in central bank money thanks to a wholesale CBDC solution. However, further experimentation, analysis and policy works are needed, before issuing a wholesale CBDC. In April 2023, the Eurosystem decided to explore new technologies for wholesale central bank money settlement with a series of experiments and trials with market participants. The DL3S solution that was tested in the Venus project, is one of the solutions offered to the institutions that applied to the call for interest to settle tokenised transactions in central bank money. Further conclusions on the DL3S solution are expected by mid-2025.

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