Implementation Models for Banks in the Context of the Digital Euro

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December 2025

Abstract

This paper analyses technical implementation models for connecting bank back-ends to the Eurosystem's Digital Euro Service Platform (DESP). Using document review, experimentation reports, and architectural modelling, it evaluates API integration choices (REST vs. gRPC), data model mapping (pseudonymisation and aliasing), Dedicated Cash Account (DCA) management, and advanced features such as conditional payments and offline transaction synchronization. The study compares microservices, monolithic and hybrid patterns and produces tier-specific blueprints for High-, Mid-, and Low-tier banks under In-house, Vendor, and Hybrid delivery models. The contributions include concrete integration patterns, sample API schemas, and best-practice recommendations for secure, performant, and maintainable bank-DESP integrations.

Keywords: Digital Euro, DESP, Dedicated Cash Account, API integration, CBDC, bank architecture

1 Introduction

The digital euro, as a retail central bank digital currency (rCBDC), emerges as a pivotal innovation in the Eurosystem's efforts to adapt central bank money to an increasingly digitalized economy. Defined in the ECB's glossary as "the digital form of the single currency available to natural and legal persons," it functions as a central bank liability offered to the general public for retail payments, encompassing individual users, businesses, and public authorities. This initiative addresses the evolving payment landscape where cash usage is declining—evidenced by a shift toward digital transactions that now dominate daily commerce—while ensuring continued access to a public, trusted, and universally accepted means of payment. Complementary to physical cash, the digital euro aims to preserve freedom of choice, bolster Europe's monetary sovereignty, and foster innovation in payments, making European systems more competitive, resilient, and inclusive. As highlighted in the Eurosystem's closing progress report on the preparation phase, the project responds to challenges such as market fragmentation dominated by non-European platforms and the need for secure, privacy-enhanced digital alternatives.

The project's evolution began with the investigation phase (2021-2023), which primarily focused on conceptual design, followed by the two-year preparation phase (November 2023 to October 2025). During preparation, key achievements included drafting the digital euro scheme rulebook—a single set of rules, standards, and procedures for basic payment services—selecting providers for the DESP and infrastructure, conducting user research and experimentation (e.g., via the Pioneer Workstream on conditional payments), and performing in-depth technical analyses. The rulebook, developed in collaboration with the Rulebook Development Group (RDG), standardizes user experiences while incorporating optional provisions to support innovation and interoperability. In October 2025, the ECB's Governing Council decided to advance to the next phase, emphasizing technical capacity building, market engagement, and legislative alignment, with potential pilots in 2027 and first issuance targeted for 2029, contingent on EU legislation adoption in 2026. This progression underscores the project's strategic response to digitalization, as outlined in recent ECB strategy documents.

Central to the ecosystem is the Digital Euro Service Platform (DESP), the core settlement infrastructure that enables transaction processing, privacy-enhanced data handling, and features like conditional payments (automated fund reservations for scenarios such as e-commerce) and offline functionality (secure transactions during network outages). Banks, acting as payment service providers (PSPs) and access managers, play a critical intermediary role in facilitating user access, managing aliases, configuring waterfall accounts, and integrating with DESP. However, implementation poses significant technical challenges, including mapping internal data models to pseudonymized Digital Euro Account Numbers (DEANs), automating Dedicated Cash Accounts (DCAs) for liquidity, and ensuring compliance with privacy standards that segregate data to prevent ECB access to personal identities. Studies, such as the PwC Digital Euro Cost Study (June 2025) and ECB's October 2025 assessment, estimate investment costs for euro area banks at €4-5.8 billion, adjustable downward through synergies like shared outsourcing and collaboration histories. These costs encompass back-end adjustments, API integrations (e.g., REST for simplicity or gRPC for performance), and architectural adaptations, with potential for mutualization reducing expenses by 30-50 percent in mid-tier markets.

Research indicates that while the digital euro could enhance efficiency and reduce reliance on foreign platforms, challenges persist, including risks of bank disintermediation (where users shift holdings to CBDC accounts), cyber vulnerabilities, and accessibility issues for non-digital populations. The IMK Study (September 2024) warns of potential failure scenarios, such as low adoption mirroring other CBDCs, or inefficiencies in offline modes, contrasting the ECB's commitment with more cautious approaches by peers like the Federal Reserve. Counterarguments from European issuers emphasize strengthening euro stablecoins alongside the digital euro to mitigate dollar dominance in stablecoins, which could undermine monetary policy. Social me-

dia discussions highlight public concerns over surveillance and control, urging balanced privacy measures.

This thesis investigates the technical architecture and system integration required to connect commercial bank back-ends to DESP, analyzing pathways like API selection, data model mapping, DCA automation, conditional payments processing, and offline synchronization. It evaluates architectural patterns—microservices for modularity versus monolithic for simplicity—and their impacts on latency, security, and maintainability. The primary objective is to deliver technical blueprints and best practices tailored to high-tier (large, advanced IT banks using in-house models), mid-tier (regional banks with hybrid approaches), and low-tier (small banks relying on vendors), ensuring cost-efficient, scalable, and compliant implementations.

Key research questions include: How can banks effectively map internal customer IDs to DEANs while automating DCAs? What are the trade-offs between REST and gRPC in high-volume environments, and microservices versus monolithic patterns in terms of system performance? How do advanced features like conditional payments (tested in the Pioneer Workstream) and offline sync influence back-end design? Which implementation models are optimal for different bank tiers, considering costs and risks?

The scope is confined to technical back-end aspects for euro area banks, drawing on ECB documents, cost studies, and global CBDC comparisons, but excludes front-end interfaces, macroeconomic effects, or non-technical regulations. Limitations arise from reliance on publicly available data and assumptions about DESP specifications, which may evolve post-2025.

2 Background on the Digital Euro

2.1 Conceptual framework

The digital euro represents a retail central bank digital currency (rCBDC), defined in the European Central Bank's (ECB) glossary as a central bank liability in digital form offered to the general public, including individual users, businesses, and public authorities, for retail payments (European Central Bank, 2023). As the digital form of the euro area's single currency, it serves as a public, trusted, and universally accepted means of payment, complementing physical cash without replacing it. This initiative addresses the declining use of cash amid rising digital transactions, aiming to preserve monetary sovereignty, enhance payment efficiency, and foster inclusivity in Europe's financial ecosystem (European Central Bank, 2025a).

The digital euro ecosystem involves multiple stakeholders with distinct roles. Users, encompassing natural and legal persons, interact with the system for everyday transactions such as person-to-person (P2P) payments, point-of-sale (POS) purchases, and e-commerce. Payment service providers (PSPs), primarily banks acting as access managers, facilitate user onboarding, manage aliases (e.g., linking phone numbers or emails to pseudonymous Digital Euro Account Numbers or DEANs), configure waterfall accounts for holding limit enforcement, and provide form factors like mobile apps or cards. The Digital Euro Service Platform (DESP) acts as the core settlement infrastructure, operated by the Eurosystem (the ECB and national central banks), handling transaction validation, privacy-enhanced data segregation, and settlement without direct access to user identities. This two-tiered model positions PSPs as intermediaries, ensuring privacy compliance through pseudonymization while delegating back-end operations to DESP (European Central Bank, 2025b). The framework draws on existing standards like the Single Euro Payments Area (SEPA) to promote interoperability and mitigate market fragmentation dominated by non-European platforms.

2.2 Eurosystem's Digital Euro Project Evolution

The Eurosystem's digital euro project has progressed through structured phases, reflecting a cautious yet ambitious approach to CBDC implementation. The investigation phase (2021-2023)

concentrated on conceptual design, exploring user needs, technical feasibility, and economic implications, culminating in a decision to advance based on positive assessments of privacy, usability, and financial stability (European Central Bank, 2023).

The subsequent preparation phase (November 2023 to October 2025) laid foundational groundwork for potential issuance. Key objectives included drafting the digital euro scheme rulebook—a comprehensive set of rules, standards, and procedures for basic payment services—selecting providers for DESP components, conducting experimentation, and engaging stakeholders. Achievements encompassed the rulebook's development in collaboration with the Rulebook Development Group (RDG), incorporating over 2,000 market comments to standardize user experiences while allowing optional provisions for innovation. Providers were selected via public tenders, with private companies and six national central banks tasked with delivering infrastructure elements. Experimentation via the innovation platform involved approximately 70 participants, including banks, fintechs, and merchants, testing conditional payments (e.g., automated fund reservations) in sectors like e-commerce and mobility, yielding insights into practical applications and technical viability (European Central Bank, 2025b). User research and technical analyses further refined aspects like security and accessibility.

As of December 2025, the project has transitioned to the next phase following the ECB's Governing Council decision in October 2025. This phase emphasizes technical capacity building, deepened market engagement, and support for the EU legislative process. If the necessary regulation is adopted in 2026, a pilot could commence in 2027, with first issuance targeted for 2029 (European Central Bank, 2025a). This evolution contrasts with global CBDC efforts; for instance, the IMK Study's CBDC tracker highlights the ECB's strong commitment as unique among advanced economies, where many, including the Federal Reserve, have ruled out retail CBDCs due to risks of low adoption and inefficiency (Bofinger, 2024). Early adopters like the Bahamas' Sand Dollar (launched 2020) and China's e-CNY (piloted since 2020) have shown mixed results, with limited uptake in the former and broader integration in the latter, informing the ECB's risk-mitigation strategies (Central Bank of The Bahamas, 2019; Zhang, 2025).

Phase	**Period**	**Key objectives and milestones**
Investigation	2021–2023	Conceptual design, feasibility studies; decision to proceed to preparation.
Preparation	2023–2025 (closed October 2025)	Rulebook drafting; provider selection (private and NCBs); innovation platform with ∼70 participants testing conditional payments; user research and stakeholder engagement.
Next Phase	Post-October 2025 onward	Technical readiness; market collaboration; legislative support; potential pilot in 2027 if regulation adopted in 2026.
Potential Issuance	2029 (target)	Full rollout contingent on EU laws; focus on scalability and privacy.

Table 1: Project phases, periods and key objectives/milestones.

2.3 Key Components of the Digital Euro Infrastructure

The digital euro's infrastructure is designed for robustness, privacy, and efficiency, comprising interconnected elements that support seamless transactions.

The DESP serves as the central platform for transaction settlement, employing privacy-enhanced techniques to segregate data and delegate handling to external providers, ensuring

no linkage of transaction details to user identities by the ECB. It includes sub-functionalities like offline modes, which enable secure, tamper-resistant transactions in network-outage scenarios through atomic synchronization upon reconnection, enhancing resilience for remote or underserved areas (European Central Bank, 2025b).

Dedicated Cash Accounts (DCAs) provide mechanisms for liquidity management, allowing users to fund digital euro holdings from commercial bank accounts via automated processes like waterfall (converting excess holdings to bank money) and reverse waterfall configurations. This ensures compliance with holding limits while maintaining liquidity flow between traditional and digital systems (European Central Bank, 2025b).

Bank-specific value-added services (VAS) offer opportunities for PSPs to extend beyond mandatory functions, fostering innovation and revenue generation. For instance, banks can integrate programmable payments, such as instalment options akin to "Buy Now, Pay Later" schemes, where conditional logic automates repayments based on predefined triggers. Merchant loyalty integrations could link digital euro transactions to rewards programs, while enhanced analytics for fraud detection and automated cash management tools (e.g., real-time balance optimization) differentiate offerings. These VAS leverage DESP's interoperability, enabling banks to compete with fintechs and reduce reliance on third-party platforms, potentially generating new income streams amid estimated implementation costs of €4-5.8 billion euro area-wide (PwC, 2025; Zhang, 2025).

2.4 Role of Banks in the Ecosystem

Banks, as supervised PSPs and access managers, are pivotal intermediaries in the digital euro ecosystem, bridging users and DESP. They handle access management (e.g., opening accounts, managing aliases), liquidity provisioning through DCAs, and transaction facilitation, including advanced features like conditional payments. This role extends to configuring waterfall accounts for limit enforcement and providing acceptance solutions like POS terminals (European Central Bank, 2023).

Synergies with existing SEPA infrastructures are emphasized, allowing banks to reuse standards for QR codes, NFC payments, and alias-based transfers, thereby reducing integration costs and promoting pan-European uniformity. By mitigating current market fragmentation—where non-European providers dominate digital payments—the digital euro enables banks to roll out innovative solutions, enhancing competition and resilience. However, challenges like potential disintermediation (e.g., deposit shifts to CBDC accounts) and high adaptation costs underscore the need for strategic responses, as critiqued in analyses of global CBDCs (Bofinger, 2024; PwC, 2025).

Bank Tier	Primary Affected Components	Cost Range (€ million per Bank)	Key Integration Challenges	Mitigation via Synergies
High-Tier (Large, Advanced IT)	Custom back-ends, APIs, full DESP services (e.g., conditional payments)	500+	Scalability for high-volume transactions; pseudonymisation	In-house expertise; cloud/hybrid deployments; hybrids (20–30% reduction)
Mid-Tier (Regional, Moderate Maturity)	Hybrid APIs, DCA automation, compliance/orchestration modules	100–300	Vendor dependencies; offline synchronization	Mutualisation with peers and shared outsourcing (30–50% reduction)
Low-Tier (Small, Basic Infrastructure)	Outsourced interfaces, basic front-ends, databases	10–50	Limited customization; security upgrades	Full vendor models; ECB-provided standards and reference implementations (40%+ reduction)

Table 2: Indicative costs, affected components, integration challenges and mitigation synergies by bank tier.

3 Literature review

4 Methodology

5 DESP and bank back-end architectures

6 Integration pathways and API choices

7 Evaluation of architectural patterns

8 Implementation models by bank tier

9 Technical blueprints and best practices

10 Conclusion

Acknowledgments