STABLEO

WHITEPAPER

Stableo: A MiCAR-compliant *euro* stablecoin backed by EU sovereign bonds

Version 1.0 – August 2025

www.stableo.co

Executive summary

Stableo is a euro-denominated, asset-referenced stablecoin designed for the post-MiCAR era of institutional-grade digital finance. It bridges the gap between traditional monetary systems and decentralized infrastructure by providing a compliant, transparent and programmable digital *euro*, fully backed by short-term Eurozone sovereign bonds. In a market dominated by USD-denominated stablecoins, and amid sweeping regulatory realignment across the EU, Stableo offers a legally robust and economically resilient alternative for European institutions, fintechs and DeFi applications.

Today's euro-backed stablecoins are fragmented, undercapitalized, or non-compliant. Stableo directly addresses:

- Regulatory void: Most stablecoins lack MiCAR[1] alignment and are being delisted from EU platforms.
- Institutional exclusion: No *euro* stablecoin currently meets the reserve, custody, or liquidity requirements of asset managers, pension funds, insurers or regulated corporations.
- Infrastructure gaps: USD dominance in DeFi introduces FX exposure, limiting euro-native financial innovation.

Stableo provides a compliant and composable *euro* liquidity rail unlocking real-time settlement, programmable payments, and compliant integration with both traditional and Web3 financial systems:

- Stableo is powered by a vertically integrated architecture that combines real-world Eurozone government bond reserves with on-chain transparency and automation:
- Reserve-backed design: Each €O token is fully backed 1:1 by a dynamically laddered portfolio of AAA/AA-rated, short-duration eurobonds.
- Smart contract logic: All issuance and redemptions are governed by deterministic smart contracts that enforce reserve constraints, compliance conditions, and upgradeable governance.
- Oracle framework: Multiple decentralized oracle contracts (BondPriceOracle, CustodyProofOracle, FiatBalanceOracle) verify asset holdings, price feeds, and Net asset value (NAV) — delivering automated, tamper-resistant solvency assurance.
- Modular design: The protocol architecture allows for scalable integrations across tokenized securities, institutional APIs, and DeFi platforms.

Stableo is engineered to be fully MiCAR-compliant from day one:

- Asset Referenced Token (ART) classification under MiCAR, with full legal registration in the EU.

[1] Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets, and amending Regulations (EU) No 1093/2010 and (EU) No 1095/2010 and Directives 2013/36/EU and (EU) 2019/1937 (Text with EEA relevance)

- All reserves are held in bankruptcy-remote custody accounts with regulated custodians (e.g. Euroclear participants).
- Fiat flows are managed via licensed EMI partners and PSD2-compliant APIs.
- MiCAR Article 36 disclosures, daily attestation of reserves, and robust governance practices are built-in.
- Designed for interoperability with the European Central Bank's upcoming Digital Euro (CBDC) infrastructure.

Stableo's operating model is designed around sustainable utility and low-friction institutional onboarding:

- Revenue generation: Yields from sovereign bond holdings fund operational expenses, buffers, and user incentives.
- Low Customer acquisition cost (CAC): B2B integration-first approach targets fund managers, digital treasuries, and fintech infrastructure providers via APIs and compliant partner networks.
- High Customer lifetime value (LTV): Composability in DeFi and compatibility with programmable finance drives long-term retention and usage across liquidity, lending, and payment ecosystems.
- Capital flywheel: As assets under management (AUM) grow, yield revenues expand, enabling stronger buffers and deeper liquidity pools, reinforcing trust and adoption.

Stableo incorporates advanced systemic risk protection aligned with MiCAR, DORA, and institutional risk appetite:

- Multi-oracle verification: Bond prices and custody data are independently verified through redundant feeds and fallback mechanisms (Chainlink, Euroclear, ECB).
- Circuit breakers: Smart contract-based logic dynamically throttles or halts redemptions and minting during anomalous events — based on volatility spikes, redemption surges, or oracle drift.
- Real-time Net asset value (NAV) enforcement: Every €O token issued is validated against current reserve value. Under-collateralized minting is automatically rejected.
- Dynamic buffers: Fiat liquidity buffers are maintained based on statistical models (e.g. 4σ redemption thresholds), updated in real-time, and stress-tested regularly.
- Governance oversight: Upgrades and risk parameters are managed through a hybrid governance model involving protocol multisigs and optional DAO participation.

In sum, Stableo is more than a *euro* stablecoin — it is a sovereign-grade digital *euro* designed for programmable finance, MiCAR compliance, and long-term systemic integrity.

1. Introduction

1.1 Evolution of Digital finance

The past decade has witnessed a transformative evolution in financial infrastructure, driven by the rise of blockchain technology and digital assets. Cryptocurrencies such as Bitcoin and Ethereum have established new paradigms for decentralized value exchange, offering global, permissionless, and censorship-resistant alternatives to traditional banking systems. However, their inherent volatility has limited their practical use as stable mediums of exchange or reliable units of account.

To bridge this gap, stablecoins have emerged as a foundational component in the digital asset ecosystem. By pegging the value of digital tokens to fiat currencies, stablecoins provide the price stability necessary for payments, remittances, savings, and decentralized finance (DeFi) protocols. In doing so, they offer users the ability to transact and store value on-chain without the volatility risk associated with native cryptocurrencies.

Despite their rapid adoption, most stablecoins to date have relied on models that lack regulatory clarity, transparent reserve management, or alignment with the monetary and financial stability frameworks of sovereign jurisdictions. In particular, Euro-denominated stablecoins remain significantly underdeveloped compared to USD-backed counterparts, limiting the euro's reach and usability within the global digital economy.

1.2 Vision for Stableo

The issuer of Stableo is SIA "Waterstone Advisers", a legal entity incorporated in Latvia, with registration number 50203155241, seeking authorization under Article 15 of the Markets in Crypto-Assets Regulation (MiCAR) as an issuer of Stableo. The company is in the process of submitting a whitepaper to the Bank of Latvia.

Stableo is designed to address this market gap by providing a fully reserved, Euro-denominated stablecoin, transparently backed by high-quality liquid assets (HQLA) in the form of Eurozone government bonds and segregated cash reserves. Built from the ground up to comply with the European Union's MiCAR, Stableo serves as a digital embodiment of the *euro* - delivering monetary stability, legal clarity and operational transparency.

Stableo's architecture ensures that each token is redeemable at a 1:1 ratio for euros, with reserves held in bankruptcy-remote structures and custody frameworks aligned with MiCAR's e-money token (EMT) classification. Unlike stablecoins that depend on commercial bank deposits or corporate debt instruments, Stableo eliminates counterparty and credit risk by holding sovereign debt securities with the highest credit ratings (AAA/AA) and short to medium durations.

Through its regulatory-first design and euro-native approach, Stableo aims to become the trusted digital *euro* for use across institutional finance, digital commerce, decentralized platforms, and embedded payment infrastructures. By ensuring verifiable backing, regulatory compliance and robust financial safeguards, Stableo paves the way for the *euro* to become programmable, composable and universally accessible in a digital-first world.

1.3 Vision and Mission

The vision of Stableo is to redefine euro-denominated value transfer in the digital economy, enabling seamless and borderless transactions across traditional and decentralized ecosystems.

Our mission is to:

- Deliver a euro-backed digital currency that is fully compliant, transparent and resilient.
- Empower individuals, businesses and institutions with trustworthy and programmable *euro* liquidity.
- Foster financial innovation while maintaining adherence to EU monetary policies and risk management standards.
- Serve as a compliant on-chain settlement layer for both regulated financial institutions and Web3-native applications.

Stableo is committed to upholding the principles of monetary integrity, consumer protection and financial stability, as defined by the MiCAR and aligned with broader European policy objectives.

1.4 Market landscape: Current trends & Regulatory context

By early 2025, the total stablecoin supply reached approximately $364 billion, up ~15% YTD. USDT (Tether) leads with over $155 billion, followed by USDC at ~$61 billion showing US dominance[2]. Notably, PayPal's PYUSD surged to ~$775 million in three months, illustrating increasing institutional and fintech-native issuance[3]. The euro-backed space (EURC, EURT, agEUR, etc.) remains niche: individual euro stablecoins typically hold comparably much smaller amounts in circulation[4]. Circle's EURC has obtained MiCAR compliance and operates alongside USD Coin (USDC) in EU markets[5].

MiCAR became fully applicable by December 2024, establishing a unified EU framework that mandates licensing, reserve oversight, e-money token treatment and anti-money laundering requirements[6]. Exchanges (Coinbase, Kraken, Bitpanda) have started delisting non-compliant stablecoins like USDT, PYUSD, and USDC (initially subject to MiCAR transitional rules) to meet regulatory deadlines[7]. With this regulatory shift, compliance-aligned *euro* stablecoins stand to benefit significantly. Meanwhile, preparations for the ECB's Digital Euro (CBDC) continue, with pilot architecture and policy work extending into 2025-2028. In parallel, private *euro* stablecoins, especially

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[2] Stablecoin Market Cap Surges 15% in 2025, USDC Gains 16% Market Share
[3] Amberdata 2025: Q1 Stablecoin Market Intelligence Report
[4] Euro-based stablecoins
[5] Circle's MiCA compliant stablecoins
[6] Markets in Crypto-Assets Regulation (MiCAR)
[7] Coinbase to delist some stablecoins in Europe ahead of new regulations

those that are MiCAR-compliant, can serve as an essential bridge between on-chain finance and CBDC architecture.

While USD-based stablecoins dominate globally, Europe's regulatory transformation and financial infrastructure (ECB CBDC roadmap, corporate issuers, compliant *euro* coins) highlight a market opening for a fully MiCAR-aligned, transparent, sovereign-backed *euro* stablecoin, offering real utility and institutional readiness in 2025 and beyond.

2. Problem statement

Despite accelerating demand for digital cash equivalents and stable-value instruments in Europe, the market still lacks a euro-pegged digital asset that meets the rigorous expectations of institutional capital allocators, particularly within regulated investment environments. The advent of the MiCAR has removed many unregulated players from the European stablecoin space, but this has not yet led to the emergence of a dominant, institutional-grade *euro* stablecoin.

Today's euro-denominated stablecoins are either too small, too opaque or technologically limited to meet the liquidity, transparency, and operational efficiency requirements of money market funds, pension funds, insurance companies, investment managers, and high-volume enterprise users. The fragmented and underdeveloped state of this market creates an extraordinary opening for a MiCAR-compliant, programmable and trust-maximized *euro* stablecoin that can serve as the foundational layer for sovereign-aligned digital finance.

2.1 The Volatility problem in traditional crypto assets

Crypto-native assets such as Bitcoin (BTC), Ethereum (ETH), and altcoins have historically been excluded from the balance sheets of traditional funds and institutional investors due to their extreme volatility, uncertain regulatory classification and lack of predictable risk profiles. Even tokenized securities and digital bonds face significant operational frictions, custodial limitations and legal ambiguities that limit their use in near-cash or liquidity portfolios.

[8]

[8] BTC price movements, Google snapshot 08.06.2025

Stablecoins were meant to address this by providing a fiat-referenced, stable-value instrument, but in practice, most stablecoins are USD-denominated and domiciled outside the EU, with unclear compliance structures and minimal usability in MiCAR-compliant financial systems. This problem is particularly acute in sectors requiring stable unit-of-account functionality, such as payroll, invoicing, cross-border trade and decentralized finance (DeFi) applications. Volatility reduces user trust, impedes financial forecasting, and hinders the mainstream use of digital assets in regulated financial systems. Despite Bitcoin's recognition as a form of digital gold or a long-term investment vehicle, its instability precludes its adoption for transactional utility within compliant economic zones such as the European Union.

2.2 The Institutional void in *euro* stablecoins

MiCAR was enacted to establish a harmonized legal framework across EU member states and went into full effect in December 2024. MiCAR mandates that issuers of asset-referenced tokens and e-money tokens operate with full regulatory approval, maintain liquid and segregated reserves, subject themselves to external audits and offer redeemability at par value. It also imposes reporting, governance and anti-money laundering requirements on crypto-asset service providers (CASPs). In response to this regulation, major EU-based exchanges such as Bitstamp, Uphold and Kraken have started delisting non-compliant stablecoins, including Tether's USDT and, in some instances USDC, thereby shrinking market access to commonly used stablecoins across European platforms. Although transitional relief was provided, this phase is ending rapidly, and many US-based stablecoins are not expected to meet MiCAR requirements due to legal and operational differences. As a result, liquidity is shifting away from centralized exchanges, and many users are caught between compliance and utility, with no viable euro-native, regulated digital cash solution in sight. This presents a unique opportunity for a new breed of stablecoin issuers to address this gap.

In parallel to private stablecoin developments, the European Central Bank (ECB) is progressing with its Digital Euro (CBDC) initiative. However, while the ECB has concluded its investigation phase and moved into the preparatory phase, full deployment is not expected before 2027-2028. The design of the Digital Euro remains cautious, particularly regarding privacy, programmability, interest-bearing features, and the role of intermediaries. Crucially, the Digital Euro is not intended to serve the same roles as private stablecoins: it is likely to be non-programmable, non-interest bearing, and distributed through tightly controlled financial channels. Moreover, it will likely be capped or constrained to avoid disintermediating banks. This leaves space for complementary, private, euro-pegged digital assets that can be used freely within smart contracts, tokenized real-world assets, and cross-chain DeFi environments, provided they meet legal and systemic standards.

While several euro-denominated stablecoins have emerged (e.g. Circle's EURC, Tether's EURT, Angle Protocol's agEUR, and Monerium's EURe), the total circulating supply of *euro* stablecoins remains below €500 million collectively[9]. This stands in stark contrast to the hundreds of billions held in USD stablecoins.

[9] https://www.ecb.europa.eu/pub/pdf/ire/focus/ecb.irebox202206_05~9f49f44d15.en.pdf

The European stablecoin market has failed to produce a dominant, secure and liquid euro-pegged digital asset capable of institutional-scale adoption. Reasons include:

- Undercapitalization: No *euro* stablecoin has achieved sufficient scale or volume to become a default *euro* liquidity vehicle for institutions.
- Regulatory grey zones: Most existing *euro* stablecoins have either failed to register as e-money tokens under MiCAR or lack clarity on their issuer structure, reserve protection, or redemption mechanisms.
- Lack of financial ecosystem integration: They are rarely integrated into regulated broker-dealers, fund platforms, or enterprise treasury systems. They often require conversion into USD stablecoins for DeFi or trade finance participation, adding friction and exposure to foreign-currency risks.

Europe's largest capital allocators like money market funds, pension funds, insurers, and family offices have no safe, compliant, digital euro-native instrument to hold or transact at scale.

2.3 Why existing Financial instruments are not enough

Conventional financial products (e.g. sovereign bonds, cash accounts, money market instruments, tokenized securities) are constrained by one or more of the following:

- Lack of Real-time settlement: Most systems still operate on T+1 or T+2 cycles, making them unsuitable for DeFi, 24/7 digital treasury, or smart contract-based transactions.
- Limited programmability: Securities and cash accounts are not programmable, preventing their use in automated yield strategies, decentralized credit, or embedded payments.
- Inadequate liquidity portability: Moving large cash or securities positions between asset managers, banks, or across borders is slow, costly, and operationally heavy.
- FX exposure: Holding USD stablecoins to avoid *euro* volatility exposes euro-zone funds to basis risk and regulatory constraints under Solvency II and UCITS frameworks.

2.4 Market opportunity: Stableo as a strategic *euro* liquidity rail

Stableo addresses this market void by providing a MiCAR-compliant, euro-pegged, fully reserve-backed, and programmable stablecoin specifically designed to meet the security, liquidity, transparency, and composability demands of institutional investors and programmable financial infrastructure.

Stableo’s strategic advantages:

1. Regulatory certainty
    - Issued as a registered asset referenced token (ART) under MiCAR.
    - Setup level as of registered e-money token (EMT) under MiCAR.
    - Full AML/CTF compliance via authorized agents.

- Distributed through audited, regulated Virtual Asset Service Providers (VASPs).
- Enables EU-based investors to hold digital cash within regulated mandates (e.g., AIFMD, UCITS, Solvency II).

2. Full reserve transparency
   - 100% reserve-backed by short-term European sovereign instruments or cash at ECB-partnered institutions.
   - Real-time proof-of-reserves on-chain with independent third-party attestations.
   - Bankruptcy-remote structure with full redemption rights at par (1:1 EUR).
3. Superior liquidity design
   - Instant issuance and redemption via API[10] and fiat rails (SEPA Instant, SWIFT, TARGET2).
   - Secondary liquidity via on-chain automated market makers (AMMs) and centralized liquidity partners.
   - High-throughput integrations with funds, custodians, and tokenized finance platforms.
4. Programmability for Institutional finance
   - Built on secure, modular smart contracts with ERC-20/ EIP-3475/ EUROe-compliant design.
   - Embedded features: transaction tagging, compliance layer, automated treasury rules, interest-bearing wrappers for fund use.
     Compatible with on-chain funds, DAO-managed capital, real-world asset (RWA) systems, and enterprise APIs.
5. Investor-grade use cases unlocked
   - Money market funds: Can park liquidity in Stableo instead of cash, enabling programmable redemption flows and 24/7 liquidity routing.
   - Pension funds & Insurers: Can use Stableo for collateralization and hedging *euro* liabilities with minimal FX friction.
   - Treasury & Asset managers: Get faster execution, cross-platform composability, and lower friction than traditional T-bills.
   - DeFi & On-chain finance: Enables euro-based DeFi lending, real-world asset tokenization, invoice financing, and yield strategies without needing USD exposure.
6. Cost and Efficiency edge
   - Lower operational friction, fewer intermediaries, and faster settlement times compared to holding short-term bonds or synthetic cash equivalents.
   - Reduces tracking error, counterparty risk, and custodial overhead for *euro* liquidity management.

[10] Application Programming Interface - a set of rules and protocols that allows different software applications to communicate with each other.

2.5 Competitive positioning

Compared to USD stablecoins, Stableo eliminates currency mismatch and legal jurisdictional friction for EU institutions. Compared to tokenized cash instruments, it offers composability, decentralization and instant settlement. Compared to other *euro* stablecoins, Stableo is the only one engineered for full institutional integration, reserve clarity and MiCAR-forward scalability. And unlike the upcoming Digital Euro, Stableo will be available sooner with full programmability and unrestricted design. Stableo is not just a digital *euro*. It is programmable, auditable, sovereign-grade cash for the 21st century.

3. Solution: Stableo design

Stableo is engineered to be the first euro-denominated, MiCAR-compliant stablecoin platform explicitly designed to serve the needs of institutional investors, regulated financial entities, fintechs, and compliant DeFi infrastructures. By fusing regulatory-grade structure with blockchain-native flexibility, Stableo addresses the current gaps in stablecoin design and unlocks a high-yield, transparent and programmable digital *euro* for the EU and global financial markets.

3.1 Architecture overview

Stableo is composed of three primary layers:

- Regulatory & Reserve layer (Trust layer)
- Tokenization & Issuance layer
- Smart contract & Service integration layer

Together, these layers create a vertically integrated, end-to-end digital asset infrastructure.

3.2 Regulatory & Reserve layer

At the foundation of Stableo lies a full reserve system backed 100% by euro-denominated sovereign bonds that are short-duration instruments from AAA/AA-rated European states (e.g., Germany, France, Netherlands):

- Yield-bearing reserves: These sovereign bonds generate consistent annual yields (currently ~2.5%–3.5%), in contrast to deposit-based models that offer no return or rely on high-risk instruments.
- Segregated custody: Reserves are held in regulated custodianship under a ring-fenced structure to ensure bankruptcy-remote protection in line with MiCAR's asset-referenced token and e-money token standards.
- Full MiCAR licensing: Stableo operates as an issuer of asset-referenced with the prospects of e-money institution (EMI), fully registered in the EU. Monthly attestations, annual audits, and real-time reserve dashboards ensure transparency and trustworthiness.
- Instant redeemability: Token holders can redeem 1:1 in fiat at any time according to internal procedure, preserving price parity and protecting against de-pegs.

This structure transforms Stableo into a transparent and yield-aligned *euro* liquidity instrument, suitable for regulated financial operations. This is the foundational layer of Stableo. It holds the real-world assets that give the stablecoin its value: short-term, high-quality euro-denominated government bonds.

Function:

- Ensures 1:1 collateralization of every issued €O token using *euro* bonds stored in regulated custodianship.
- Manages liquidity buffers in cash or near-cash equivalents to support redemptions.
- Enables yield accrual to the protocol, creating a profit layer that funds operations, returns and growth.

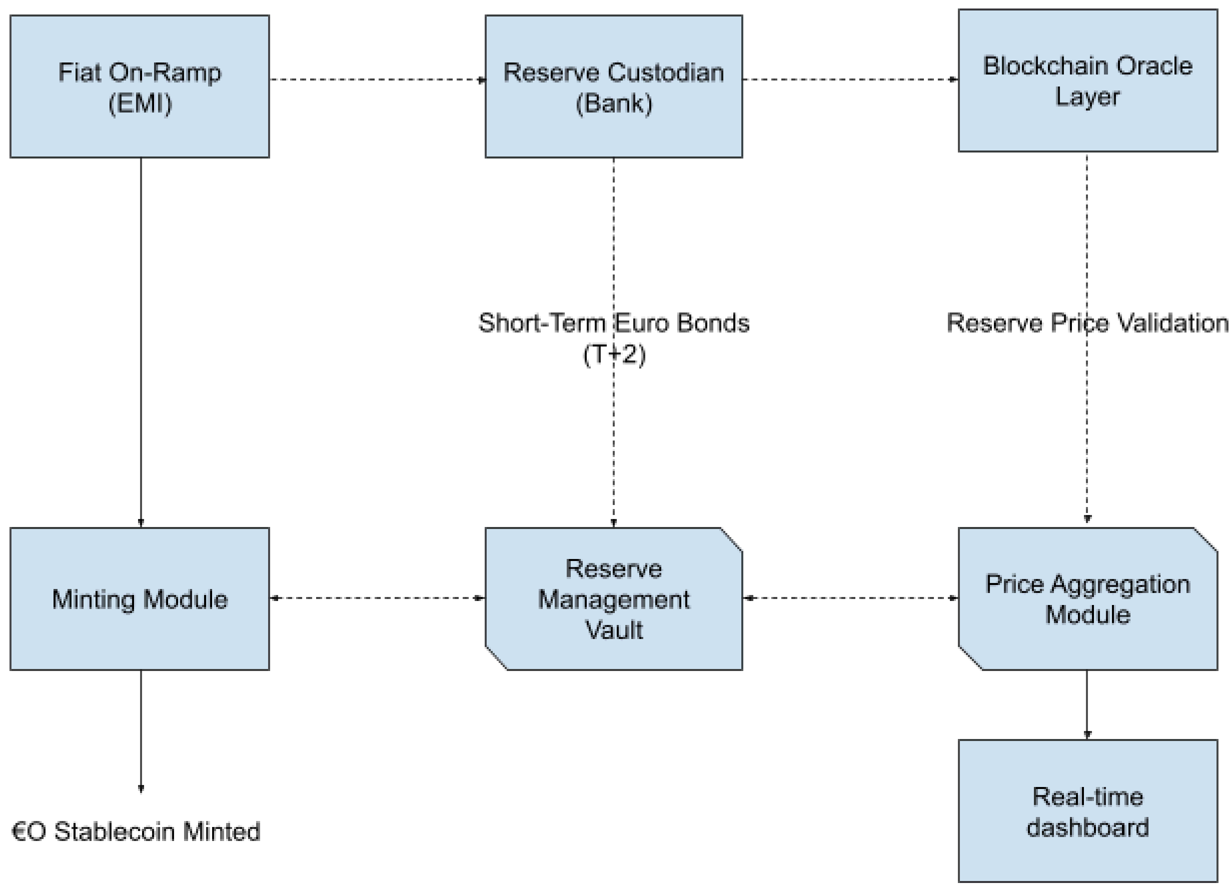
Built-in protections:

- Third-party regulated custodians hold the bonds in segregated accounts (bankruptcy-remote).
- Real-time auditing oracles broadcast daily market values of the underlying assets, using multi-source bond pricing (e.g. Bloomberg BVAL, Euroclear).
- Anti-manipulation mechanism: Pricing is taken from multiple verified market data sources and compared through consensus logic. Outlier detection and thresholds prevent false inputs from affecting valuation or redemption.

To ensure resilience, legal compliance and trust, the Regulatory & Reserve layer of Stableo integrates three key pillars: asset security, transparent operations and programmable financial logic. This is delivered using a modular architecture that is designed for long-term scalability under the EU's MiCAR regulatory framework.

System architecture & workflow

At its core, Stableo's reserve system is built on a multi-layered custody and validation stack. The flow is as follows:



Workflow Details:

- Fiat entry: Authorized counterparties send EUR to an EMI partner, acting as the compliant on-ramp. The EMI provides instant fiat settlement and compliance checks.
- Custody & Reserve purchase: Funds are programmatically directed toward purchasing approved euro-denominated sovereign bonds. These assets are held under segregated client accounts in a Tier-1 custodian bank (e.g., Euroclear participant). Depending on the selected module and purchase amount, bonds are scheduled to be converted immediately or within an agreed schedule to minimize transaction fees.
- Token issuance: Upon successful asset acquisition and verification by an independent oracle layer, the corresponding amount of €O tokens is minted 1:1 and transferred to the initiating counterparty's wallet.
- Real-time validation: Bond values are updated daily using external oracles aggregating from multiple sources (e.g., Bloomberg BVAL, Tradeweb, Euroclear). A consensus logic with fallback and outlier detection prevents price manipulation.

- Redeemability path**:** On burn requests, the system ensures sufficient liquidity buffers to fulfill same-day redemptions via the EMI, with automated treasury rebalancing to meet liquidity thresholds. Sufficient cash reserves are held to ensure both fast liquidity and price changes due to unforeseen events.

Legal & technical symbiosis

The architecture is explicitly designed to satisfy both - MiCAR's ART (Asset-Referenced Token) and EMT (E-Money Token) requirements, offering a legally robust foundation for onboarding institutional capital. Each component in this layer has both a technical role and a regulatory analogue, ensuring end-to-end auditability and compliance:

- Reserve matching engine**:** Automates bond purchases to match fiat inflows, maintaining 1:1 backing. Technically implemented via off-chain services connected to custodians; legally enforced via contractual SLAs and daily reporting.
- Smart contracts**:** Responsible for minting and burning of €O tokens, containing logic constraints that prohibit over-issuance beyond verified reserves. Fully upgradable under protocol governance.
- Liquidity buffer module**:** Maintains a pre-set percentage (e.g., 5–10%) of cash-equivalent assets for instant redemptions. Configurable via governance, monitored in real time.
- Bond valuation oracle**:** Combines verified third-party pricing APIs with internal logic for discrepancy detection and fallback to alternate data feeds, ensuring manipulators cannot exploit pricing for arbitrage or false redemptions.

Modular evolution path

The architecture supports a lean-first deployment while enabling structured expansion across legal and technical dimensions:

Phase 1 – Lean launch:

- One licensed EMI partner for fiat custody.
- One regulated custodian (bank or investment firm).
- Real-time attestation via manual and semi-automated feeds.
- Limited set of EUR bond instruments (e.g., German Schatz, French BTANs).

Phase 2 – Expansion & Resilience:

- Multiple custodians and EMI partners (to ensure redundancy and regulatory diversification).
- Integration with pan-European APIs (e.g., T2S for securities settlement, PSD2 for fiat movement visibility).
- Direct APIs to liquidity venues and bond execution platforms (e.g., MTS, Tradeweb).
- Smart contract-based circuit breakers tied to redemption thresholds and oracle stability metrics.

Phase 3 – Institutional infrastructure:

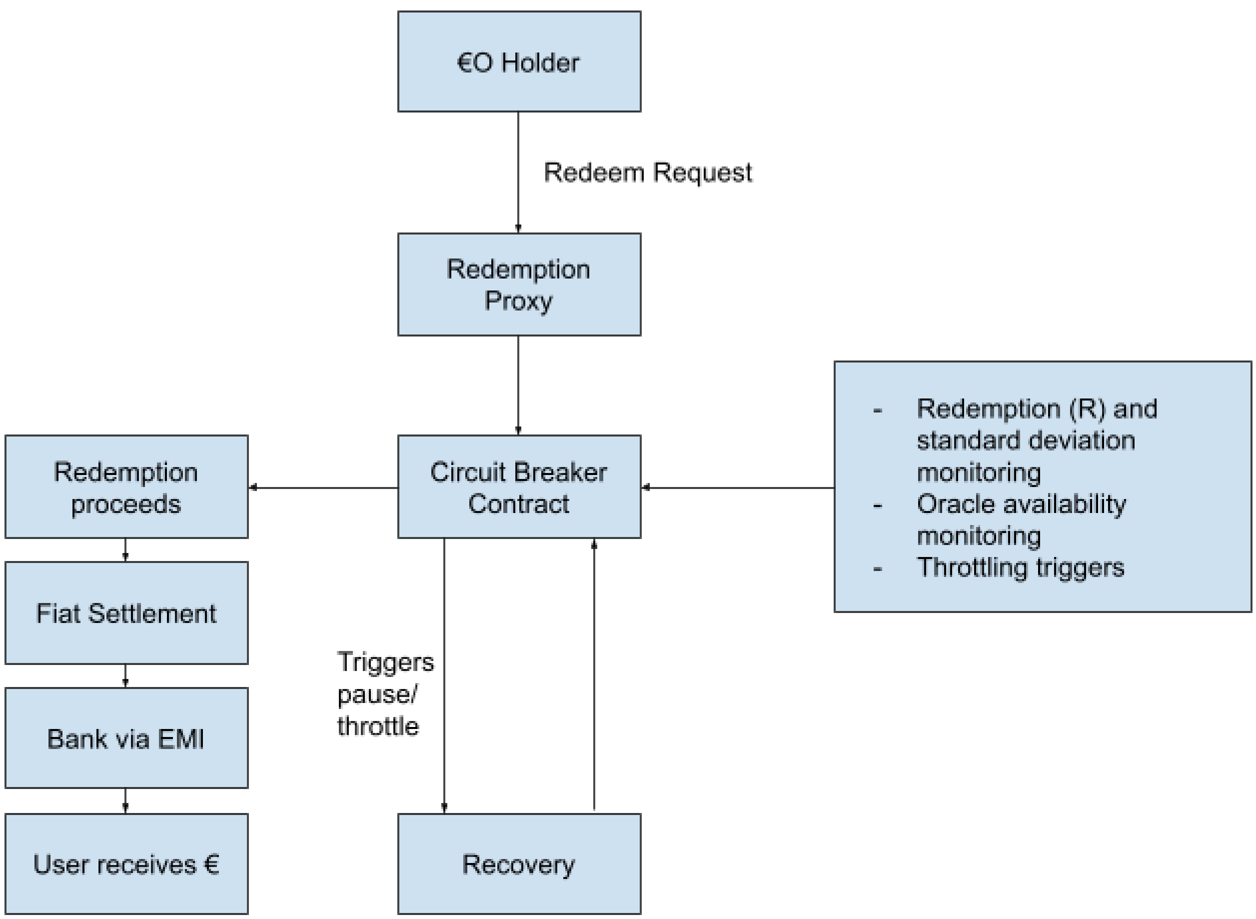
- White-label B2B issuance APIs for money market funds and digital wealth managers.
- Yield analytics dashboards for treasury and pension clients.
- Embedded Basel-compliant capital analytics and reserve stress-testing tools.

Smart contract-based circuit breakers

Circuit breakers are automated safety mechanisms embedded into the €O smart contracts that pause, throttle or adjust redemption/minting actions in real time to prevent systemic risk, destabilization or exploitation during market stress or manipulation attempts.

These mechanisms rely on:

- Redemption thresholds - how much €O is being redeemed within a time window
- Oracle stability metrics - validity and variance of price feeds or reserve asset valuations.



These thresholds are pre-defined quantitative limits that track €O token redemptions over a given time period (e.g., 1 hour, 4 hours, 24 hours). This and formulas below use standard notation and default values unless stated otherwise, and shall be adjusted to governance as per operations, stress testing and market conditions.

- k = sensitivity parameter, real number $k > 0$, default $k = 3$.
- δ = (deviation tolerance, fraction $0 > \delta > 1$, default $\delta = 0.05$.
- N = look-back window, positive integer, default $N = 30$ days.

Let:

- R_t = total €O redeemed during time period t (e.g. 30m, 1h).
- μ_R = historical average redemption volume for same period t.
- σ_R = standard deviation of redemptions over the last N windows.

We define a redemption alert or breaker level as:

$$R_t > \mu R_t + k \cdot \sigma R_t$$

Where:

- R_t = observed redemption volume at time t.
- μR_t = mean of redemption volumes over the look-back window.
- σR_t = standard deviation of those volumes.
- k = sensitivity multiplier.

Action taken:

- If the redemption rate exceeds limits, a circuit breaker is triggered.
- Throttle redemptions (rate limit: e.g., 10% AUM/hour).
- Delay settlement (convert to T+1 or T+2).
- Activate governance quorum to assess ongoing stress.

This prevents panic-driven runs that could collapse bond liquidation liquidity or depeg the token.

Example scenario

Assumptions:

- t = 30 minute time period
- R_t = €3M
- μ_R = €1M
- σ_R = €400k
- k = 3 (3 standard deviations 3σ above the mean

Trigger threshold = $\mu_R + k \cdot \sigma_R$ = €1M + (3 x €400k) = €1M + €1.2M = €2.1M

Simple check is done:

Is €3M > €2.1M? Yes. Triggered as current redemption value is significantly higher than expected.

Fat-tail safeguard is added for the redemption breaker because real-world redemption spikes follow fat-tailed distributions, extreme events may be more likely than the normal model suggests. Therefore, a secondary trigger layer is applied against the empirical 99.7th percentile of redemption volumes over a rolling window. Instead of relying on $k\sigma$ the system compares R_t against the empirical 99.7th percentile of redemption volumes over a rolling window:

$$R_t > Q_{0.997}(R)$$

Where (R) is derived from sorted recent redemption data.

Example scenario

Assumptions:

- 30-minute window
- Historical redemptions: [0.5M, 0.7M, .., 2.2M]
- Empirical 99.7th percentile = €1.9M

SImple check is done:

- $R_t > \mu + 3\sigma = 2.1M$
- $R_t > Q_{0.997} = 1.9M$

Both mechanisms reinforce the validity of the anomaly.

Exponentially Weighted Moving Average (EWMA) can be a good enhancement that is used to capture momentum or shifts in redemption behavior. Unlike a simple moving average, EWMA gives more weight to recent data to identify short-term changes like building panic with α as a tunable parameter where $\alpha \in (0, 1)$ and values closer to 1 reacts faster:

$$\mu_t^{EWMA} = \alpha R_t + (1 - \alpha)\mu_{t-1}^{EWMA}$$

Where:

- μ_t^{EWMA} = the updated exponential moving average at time t.
- R_t = current redemption volume.
- $\alpha \in (0, 1)$ = smoothing factor (closer to 1 = more responsive).
- μ_{t-1}^{EWMA} = the previous EWMA value.

This can be combined with the fat-tail safeguard to identify recent, higher than usual redemptions in combination with identifying if this redemption is statistically extreme based on past data.

$$Score_t = \omega_1 \cdot (\frac{R_t - \mu_t^{EWMA}}{\sigma_t^{EMWA}}) + \omega_2 \cdot 1_{\{R_t > Q_{0.997}(R)\}}$$

Where:

- R_t = current redemption volume
- μ_t^{EWMA} = short-term average (EWMA)
- σ_t^{EMWA} = short-term standard deviation (EWMA variant or rolling window)
- $Q_{0.997}(R)$ = 99.7th percentile from historical redemptions
- $1_{\{\cdot\}}$ = indicator function (1 if true, 0 if false)
- ω_1, ω_2 = weights for balancing short-term trend vs. tail detection

This scoring method is intended for later phases as it is highly sensitive to unusual events and catches both sudden and slow-building anomalies working well in adversarial or panic conditions. But due to the fact it can make more false positives during temporary surges (e.g., one-time redemptions from a whale) and responds quickly, can misfire if the surge is short-lived and then corrects. While this issue can be mitigated by setting a minimum duration or confirmation window (e.g., 2 consecutive periods over threshold) with the weight of the indicator function lower (w2=0.5w2=0.5) to avoid sharp one-off triggers its complexity and fine-tuning requirements places this method suitable for later stages with larger data sets available.

During bond conversion events, price feeds from oracles (e.g., Euroclear, Bloomberg BVAL, SIX, Refinitiv) are triangulated and checked for anomalies.

Let:

- P_i = the price of a bond as reported by source i (A single data point or price reading (e.g., from a specific feed))
- $\overline{P}$ = the mean price across multiple sources
- σ_P be the standard deviation across sources (e.g., 0.01 for 1%)

We define validity window:

$$|P_i - \overline{P}| < \delta \cdot \overline{P}$$

If more than $x\%$ of sources exceed this deviation (e.g., 5%), then:

- Oracles are flagged as unstable
- Smart contract rejects redemptions until new valid prices are available

This prevents manipulation by a single compromised oracle or temporary data feeds from overvaluing bonds and allowing undercollateralized redemptions. Redemption monitor oracle tracks redemptions in real-time with moving average and deviation thresholds (see Oracles section for more details) by fetching bond price feeds, calculates median, flags anomalies. Depending on the results, the state machine controls the redemption switching between redemption states (e.g. NORMAL - standard redemption, THROTTLED - rate-limited redemption, FROZEN - circuit breaker triggered, pause all redemptions, etc.). Emergency multisig or DAO-triggered reactivation with quorum.

Example scenario

Bounded deviation rule is used in oracle data aggregation for price feeds, checking if an individual price is "close enough" to the average consensus.

Assumptions:

- $\overline{P}$ = €100.00
- δ = 0.01 (1%)
- €100 ± 1% = €99.00 to €101.00

Simple check is done:

a) P_i = €98.90 -> INVALID
b) P_i = €100.80 -> VALID

This approach is used to filter out bad or manipulated feeds (delays, errors, attacks, etc.) and ensures only data points near the consensus are accepted. Further fine tuning is applied using weighted median, TWAP and historical anchors (depending on the market). This fail-safe mechanism is used for stable price aggregation - even if one or two oracles submit incorrect prices they are excluded from affecting the system. Governance can adjust the standard deviation during volatile markets (widened) or calm periods (tightened). All rejections are logged on-chain for audit and governance purposes. Rejections are monitored to fine tune the trigger.

The design must anticipate and actively mitigate operational, market risks and credit risk:

- Market price volatility of Bonds: Though short-duration bonds are relatively stable, in extreme rate hike cycles, mark-to-market fluctuations can introduce volatility. A minimum maturity laddering strategy (e.g., under 6 months) will reduce exposure. Daily valuations are weighted-average and rate-capped for update (e.g., max ±1.5%/day unless governance approval). Time-weighted average price (TWAP) + minimum hold duration before redemption ensures no immediate round-trip arbitrage.
- Liquidity mismatch risk: Redemption volumes that exceed cash buffer thresholds may require bond liquidation. Secondary market liquidity of sovereign bonds must be monitored to avoid forced sales at unfavorable prices. Rate limits and redemption windows stabilize pressure and buy time for liquidation if needed. Outlier detection and consensus-based thresholds disable redemptions if oracles drift too far.
- Custodian insolvency**:** All assets are held in ring-fenced accounts under EU investor protection laws, but additional insurance wrappers (via regulated third parties) may be added

for institutional clients. Redemption throttles automatically match liquidity buffers and portfolio realignment capacity.

Example scenario

Assumptions:

- Stableo has €100M AUM
- Daily redemptions historically average €500k
- €8M is requested in 30 minutes (R_{30m})
- €500k average redemptions in 30 minutes (μ_{30m})
- €300k standard deviation (σ_{30m})

Trigger:

$$R_{30m} = 8M > \mu_{30m} + 4\sigma_{30m}$$

Where:

- R_{30m} = Total amount of €O tokens requested for redemption in the past 30 minutes
- μ_{30m} = Historical average redemptions over any 30-minute window
- σ_{30m} = Standard deviation of those historical 30-minute redemption volumes
- $\mu_{30m} + 4\sigma_{30m}$ = trigger threshold

Checks are done weather redemption volume spike over the past 30 minutes (R_{30m}) exceeds statistically significant threshold which is defined by a historical average (μ_{30m}) plus 4 standard deviations ($4\sigma_{30m}$). In this outlier detection mechanism threshold like 4σ indicates an extremely rare event (probability <0.0063%). Once the circuit breaker is triggered. Redemptions paused for 1 hour, contract displays "cooldown in progress."

Trigger threshold = $\mu_{30m} + 4\sigma_{30m}$ = €500k + (4 x €300k) = €500k + €1.2M = €1.7M

Simple check is done:

Is €8M > €1.7M? Yes. This redemption spike is statistically extreme, likely due to panic, attack, or systemic event.

Actions on trigger:

- Set redemption status to DEGRADED, FROZEN or HALTED (depending on defined states)
- Pause mints/redemptions temporarily on oracle level
- Send out notification alerts (off-chain governance), log the event with full payloads
- Oracle feeds show one bond marked at 99.5 while others are at 100.3
- Contract flags data from Source A as invalid
- Continue throttling redemptions (e.g. per wallet daily limits)
- Waits for reconciliation across sources
- Waits for automatic or manual resume of process

As 4 standard deviations are extremely rare under normal distribution, true anomaly signals appear with high confidence. The scenarios can be adjusted to monitor longer windows (e.g., R = 1h, 24h or dynamic based on market conditions) or create wallet-specific monitoring.

Cross-correlation of events is an important feature that operates on a higher level. In systems, especially during market stress, risk signals often appear in clusters rather than isolation. For instance, during a depegging event or a coordinated attack, it's common to see spikes in redemptions coinciding with anomalies in oracle price feeds. Individually, each signal may not breach its trigger level, but together they form a meaningful pattern of systemic risk. This is why measuring cross-correlation between anomaly sources is crucial.

By combining independent indicators (such as redemption volumes and oracle deviations) into a single anomaly score, the system can more accurately determine when it is under stress. This creates a composite risk signal that is more sensitive and better tuned to reflect real threat conditions, without overreacting to single-variable noise. Composite anomaly score for time t is defined as:

$$Score_t = \omega_1 \cdot Z_t^{redemption} + \omega_2 \cdot Z_t^{oracle}$$

Where:

- $Score_t$ = overall anomaly score at time t.
- ω_1, ω_2 = weighting coefficients (e.g., 0.5, 0.5 or adjusted by risk profile)
- $Z_t^{redemption}$ = z-score of redemption volumes $Z_t^{redemption} = \frac{R_t - \mu_R}{\sigma_R}$
- Z_t^{oracle} = z-score of oracle deviation $Z_t^{oracle} = \frac{P_{max,t} - P_{min,t}}{\overline{P_t} \cdot \delta}$ (or other standardized deviation metric)
- δ = allowed deviation threshold (e.g., 1%)

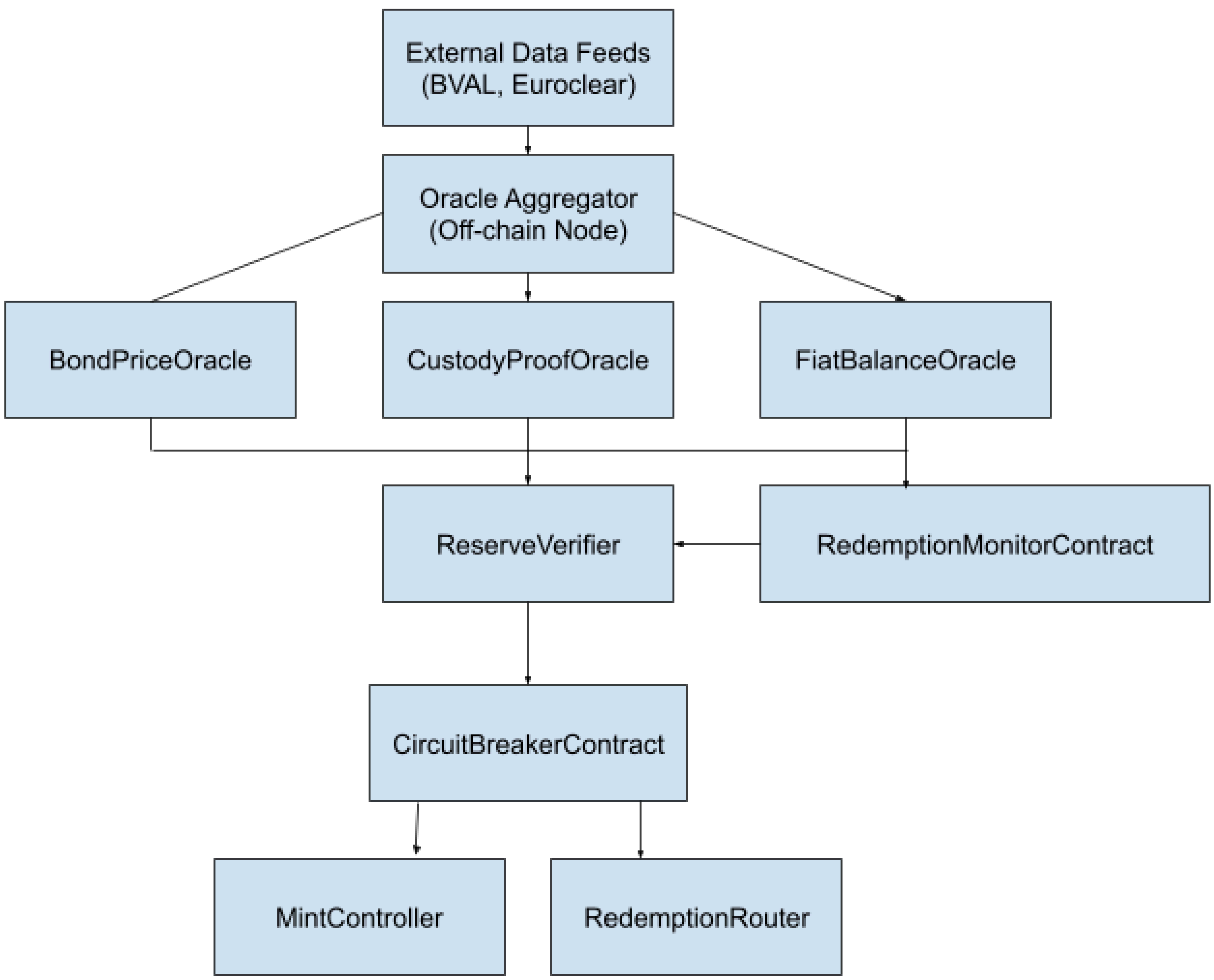
Trigger condition: $Score_t > \tau$ where τ is a calibrated risk threshold (e.g., 4.5).

This approach accounts for both magnitude and alignment of multiple independent anomalies. If either component spikes or both moderately rise together, the trigger is reached. This combined logic enhances the ability to detect complex attacks, oracle drift during redemption surges, or systemic stress with greater reliability. Can be implemented on-chain assuming gas and contract constraints allow: EWMA or rolling z-scores can be tracked and logic applied within a monitoring contract. As alternative an off-chain deployment can be introduced allowing oracle services or dashboards to continuously compute this score and push alerts or trigger flags via API or governance input.

These circuit breakers are risk-aware, mathematically bound mechanisms that align with MiCAR operational resilience expectations, protect users and system solvency and maintain fair market operations in volatile or adversarial conditions.

Oracle contracts in the Reserve layer

Oracle contracts act as bridges between off-chain financial data (bond prices, reserve balances, custody attestations) and on-chain logic (collateral verification, redemption limits, smart contract enforcement). Their core role is to validate that each €O token is backed by €1 in real-world, high-quality liquid euro-denominated government assets.



The architecture diagram outlines the interaction between real-world data sources, off-chain aggregators, and on-chain logic. External feeds like Bloomberg and Euroclear are ingested via Oracle contracts running in secure off-chain nodes. These aggregators handle signature generation and normalization of data.

Three primary oracle contracts ingest the validated data:

- BondPriceOracle - delivers sovereign bond pricing data;
- CustodyProofOracle - verifies secure asset custody;
- FiatBalanceOracle - monitors near-cash buffers.

These contracts feed the ReserveVerifier, which computes the overall NAV (Net Asset Value) and collateralization ratio. This information is used to validate minting conditions and update system transparency. Meanwhile, RedemptionMonitorContract watches for abnormal redemption behaviors, and can issue alerts or halt minting/redemption processes via status flags.

In the event of systemic stress, the CircuitBreakerContract is triggered by the monitor contract or oracle deviations. This contract imposes immediate halt on mint/redemption flows, preserving liquidity and preventing bank-run dynamics. Governance or automated cooldown can safely restore normal operations.

Downstream contracts (MintController and RedemptionRouter) are consumers of the verified oracle data. They ensure that every minted or redeemed €O token complies with real-time asset backing and system stability, completing the closed loop of trust between real-world assets and digital issuance.

Oracle contract components

Component	**Core function**	**Formula/Model type used**
CustodyProofOracle	Verifies custodial claims and holdings	Cryptographic proofs (Merkle, sigs)
BondPriceOracle	Aggregates/smooths prices	TWAP, outlier rejection, volatility
FiatBalanceOracle	Aggregates and updates cash positions	Real-time balance tracking
ReserveVerifier	Computes NAV & collateralization	Aggregation logic + enforcement
RedemptionMonitor	Monitors redemption patterns	$R_t > \mu + k\sigma$,delta NAV, delays
CircuitBreaker	Pauses mint/redeem on extreme input	Signal accumulation + governance triggers

1. BondPriceOracle

This smart contract serves as the on-chain source of truth for bond valuations, ensuring that asset prices used to calculate NAV and system risk are accurate, tamper-resistant, and transparent. The oracle aggregates daily sovereign bond prices from trusted sources - the Oracle contracts (off-chain component) collects price data from multiple independent, regulated financial sources which refers specifically to government-issued debt instruments, considered low risk. Prices are updated once per day to reflect the end-of-day official values from trusted sources. These multiple sources are cross-checked to improve reliability and resilience.

To ensure resilience against volatility or oracle downtime, the BondPriceOracle integrates a tiered fallback hierarchy for price feeds.

Priority	**Source**	**Type**	**Update frequency**	**Notes**
1	Chainlink oracles (bond feeds)	On-chain	Near real-time	Primary feed
2	Pyth network (bond data)	On-chain	<1 min	Activated if Chainlink stalls
3	ECB debt securities statistics API	Off-chain REST	Daily/Hourly	Used when on-chain sources fail
4	Euroclear or Bloomberg BVAL	Off-chain CSV	EOD	For manual override/triangulation

A staleness threshold of 10 minutes is applied to Chainlink and Pyth feeds. If no fresh data is observed within this threshold, the system activates the fallback layer. The oracle aggregates responses using a 3-of-5 quorum approach (median of available sources), discarding outliers beyond 1.5× IQR (interquartile range), e.g. if Chainlink and Pyth both fail, and ECB+Euroclear+BVAL return prices of €99.45, €99.50, and €99.70, the contract takes the median = €99.50 as fallback valuation.

The oracle applies outlier rejection, Time-Weighted Average Price (TWAP) smoothing, and signature verification to ensure accurate, resistant-to-manipulation pricing:

- Outlier rejection: If one price differs drastically (>4σ) from the others, it is discarded to prevent manipulation or data errors.
- TWAP smoothing: Instead of using the raw daily value, prices are averaged over time using a weight per time interval. This helps eliminate short-term volatility or anomalies (e.g., pricing jumps around rate announcements).

- Signature verification: All incoming data is digitally signed by the Oracle contract using a secure key. BondPriceOracle verifies that the signature comes from an approved entity and that the data wasn't tampered with during transmission.

Data is stored directly on-chain and can be referenced by other contracts for enforcement and transparency. The current NAV of the bond portfolio is stored. NAV is calculated as

$$NAV = \sum_{i=1}^{N} = P_{i,t} \times q_{i,t}$$

where

- i = individual bond in the portfolio.
- N = number of bond positions.
- $P_{i,t}$ = market price of bond at time t.
- $q_{i,t}$ = quantity held of bond at time t.

This is the total market value of all bonds held by Stableo, priced using current reliable market values which is used by ReserveVerifier to determine minting eligibility and by RedemptionMonitor to evaluate system stability.

For the last 30-day historical prices hybrid approach leveraging both Merkle trees and a conceptual sliding window on the stored data is the most robust and suitable solution. A tamper-resistance and on-chain source of truth is needed for undeniable proof of what data was stored and when (Historical access (30-day) and analytical capabilities for trend analysis, NAV recalculation (historical), and volatility assessment). In this case a pure sliding window array (as an on-chain data structure) for 30 days would be problematic for true tamper-resistance and verification over time. Once data slides out, it's gone from the "window". At the same time a pure Merkle tree would provide excellent integrity but wouldn't directly offer the analytical functions or easy "sliding window" access without off-chain processing. In result a hybrid approach must be used:

- On-chain data storage with Merkle tree principles:
  - Daily price commitments: Each day, after the oracle contracts performs outlier rejection, TWAP smoothing, and gets the final signed price for each bond ISIN, the BondPriceOracle contract will store this data.
  - Merkle hash of daily prices (Conceptual): due to gas costs a full Merkle tree is not built daily, but core principles are implemented:
    - Timestamp, ISIN, price, signature stored directly.
    - A merkle root/daily hash maintained for the entire set of prices reported for that day. This root/hash is stored alongside the daily prices. Prices for multiple ISINs are committed for each day.

        - The signature from the Oracle contract is a primary integrity check for incoming data. The Merkle root/daily hash is for stored data integrity over time.
    - Optimized On-chain storage for last 30 Days:
        - Circular Buffer/Fixed-Size Array: a fixed-size array (*mapping(DailyPriceData)) dailyPrices* with an index) to store the last 30 days of daily bond prices.
        - *DailyPriceData* Struct that contains:
            - *timestamp*
            - *pricesByISIN* (mapping ISIN hash to price)
            - hash of all prices for that day
            - *signature*
        - When a new day's data comes in, the oldest day's data is overwritten.
- Off-chain Merkle tree for long-term auditing:
    - The oracle contract (off-chain) maintains a full Merkle tree of all historical bond prices. Each daily batch of signed prices is a leaf in this larger off-chain Merkle tree.
    - The Merkle root of this full historical tree is periodically committed to the BondPriceOracle (weekly). This allows auditors to verify any historical price (even beyond 30 days) by requesting a Merkle proof from the Oracle contract and verifying it against the published Merkle root on-chain. This separates the on-chain "working data" for immediate use from the long-term archival integrity proof.
    - Enabling analytical capabilities (on-chain and off-chain):
        - On-chain (for direct contract use):
            - *getHistoricalPrice(timestamp, isinHash)*: Query the 30-day on-chain storage.
            - *getTWAP(isinHash, lookbackDays)*: Iterates over the last lookbackDays (up to 30) from the stored prices to calculate a TWAP on-chain. This directly fulfills TWAP smoothing requirement for current prices, and also allows downstream contracts to query historical TWAPs.
            - *calculateHistoricalNAV(timestamp, portfolio_details[])*: The ReserveVerifier and RedemptionMonitor contracts can call BondPriceOracle to get the necessary historical prices (within the 30-day window) and then perform their own NAV calculations.
            - No direct on-chain "trend analysis" or "volatility assessment" functions. These are complex statistical operations best done off-chain. The oracle provides the data for these analyses.
        - Off-chain (for auditors and sophisticated analysis):
            - Auditors or sophisticated analytics tools fetch the raw *(timestamp, ISIN, price)* data from the BondPriceOracle (or the off-chain Merkle tree for deeper history) which is used to:
                - Perform extensive trend analysis (e.g., using more advanced statistical models than feasible on-chain).

■ Recalculate NAVs at any historical time (using data retrieved and verified via Merkle proofs).
■ Assess pricing volatility (standard deviation, Bollinger Bands, etc.) over arbitrary periods, using the verified historical data.

Volatility calculations for circuit breaker thresholds are done daily. Daily prices are used to calculate rolling standard deviation (σ):

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - \overline{P})^2}$$

where P_i is each daily price and $\overline{P}$ is the mean. The thresholds are used by the RedemptionMonitorContract to decide if a NAV drop is abnormal (>4σ from the mean). This makes the system more adaptive - it tolerates normal market movement, but halts redemptions or mints during potential crashes or manipulations. The BondPriceOracle combines data aggregation, statistical smoothing, cryptographic verification, and historical price storage to become a robust pricing backbone of the Stableo architecture. It protects users from manipulation, while ensuring real-time trust in asset values.

2. CustodyProofOracle

This is a smart contract that acts as a bridge between off-chain regulated custodians (e.g., a bank or licensed securities depository) and on-chain logic. Its purpose is to prove that real-world assets are held in custody as declared by those entities. The contract verifies regulated custodians' signed attestations

- Attestations: These are digitally signed statements (usually JSON or binary blobs) that declare asset holdings (cash and bonds) under custody.
- Regulated custodians: Only whitelisted, licensed institutions (e.g., BNP Paribas Securities, Clearstream, Euroclear) are allowed to submit these.
- Verification: The contract checks whether the digital signature attached to the attestation was created using an approved cryptographic key belonging to a known custodian. This ensures authenticity.

ISIN-level breakdowns where data is validated off-chain, then referenced on-chain. These are the data fields inside the attestation. They are crucial for full transparency and reserve breakdown.

- ISIN-level breakdowns: Details for each bond instrument held, identified via its unique ISIN code (e.g., "DE0001102473").
- Euro cash: Declared amount of unallocated cash in euros held alongside the bonds.
- Bond types: Identifiers like government bonds, supranational bonds, short-duration notes, etc.
- Timestamps: Marks when the report was signed and when the data snapshot was taken (to prevent backdating).

On-chain after the off-chain data is received and validated, it is hashed into a flat hash. This single hash is posted to the blockchain to prove the data was submitted, but not reveal all contents (for privacy, scalability). Any third party can recompute the hash from a full attestation and verify it matches the on-chain version. This provides auditability without bloat.

The contract stores the public keys of authorized custodians. When a new attestation is submitted, it must come with a valid cryptographic signature made using the custodian's private key. This ensures that only real custodians can submit and no data tampering occurred after signing. In result all data is non-repudiable. All data entries must contain the issuer (custodian or custody entity that created the report), creation timestamp, validity window and audit tag (reference to an external audit or batch ID).

3. FiatBalanceOracle

The FiatBalanceOracle ensures real-time awareness of fiat (Euro) cash reserves in regulated banks or custodians. This oracle is a key component for maintaining short-term redemption liquidity and proving solvency at any moment. The oracle collects and consolidates balances from multiple fiat custodians and bank accounts where Stableo's reserve funds are held. Public APIs are used. For high-trust setup, direct integration may also involve SWIFT MT940/MT942 messages or ISO 20022 XML-based cash reports. These also include fintech custodians, payment processors, or regulated e-money institutions (EMIs) that hold segregated client accounts. This multi-source input ensures redundancy and breadth of coverage across the fiat layer.

Here validation that cash buffers are adequate to meet short-term redemption flows is being done. This is a key function to check that enough fiat cash is available to process expected or actual redemptions. This is compared to historical redemption rates:

$$Fiat\ holdings \geq \mu_{redemptions} + k \cdot \sigma_{redemptions}$$

This ensures that even under statistical stress scenarios (4σ spikes in withdrawals), the system has enough liquid *euros* on hand. If buffers fall below the threshold, the ReserveVerifier can automatically halt mints, delay redemptions or trigger emergency alerts or sell bonds to cover deficits.

Unlike bonds (which are priced daily), fiat balances can change in real time due to redemptions, mint inflows, interest payments or bank transfers or settlements. Therefore, the oracle updates multiple times per day on a fixed interval (every 10 minutes or upon event-based triggers). These updates allow the ReserveVerifierContract to always have a correct view of on-hand fiat liquidity, calculate real-time NAV availability and pre-approve redemptions without delay.

The FiatBalanceOracle acts as a short-term solvency monitor, ensuring Stableo's fiat base is always aligned with potential liabilities:

- Fiat aggregation - pull balances from all fiat custodians;
- Intraday updates - ensure up-to-date liquidity visibility;
- Liquidity buffer enforcement - guarantee short-term redemptions can be fulfilled;

- Data integrity - includes digital signatures or proofs of source authenticity.

4. ReserveVerifier

The ReserveVerifier is the central logic contract that combines data from all oracles to assess the overall financial health of the Stableo system in real time. It plays a critical role in enforcing solvency, minting rules and transparency. This contract ingests and consolidates data from three key sources:

- BondPriceOracle
  - Supplies the current market value of all sovereign bonds held
  - Adjusted using pricing models (e.g., TWAP, outlier rejection).
  - Expressed as the net market value in Euros.
- CustodyProofOracle
  - Provides the authenticated holdings reported by custodians.
  - Ensures that the actual ISIN-level inventory of bonds and cash aligns with claims.
  - Acts as a real-world anchoring layer: if there's a mismatch between declared and priced reserves, this module ensures data integrity.
- FiatBalanceOracle
  - Feeds in real-time fiat balances across banks and custodians.
  - This ensures sufficient liquid cash is included in NAV calculations.

The total NAV of the Stableo reserve system is calculated as:
$NAV_{total} = NAV_{bonds} + NAV_{custody} + NAV_{fiat}$. Each component is adjusted for verification trust level and real-time freshness.

The collateral ratio is recalculated every time new data is received from any oracle. It's published on-chain for full transparency and used to gate minting/redemption logic and is calculated:

$$Collateral\ Ratio = \frac{NAV_{reserve,t}}{Supply_{Stableo,t}}$$

Where:

- $NAV_{reserve,t}$ = total reserve net asset value at time t.
- $Supply_{Stableo,t}$ = total Stableo tokens outstanding at time t.

If the ratio is ≥1.00, Stableo is fully collateralized or overcollateralized, while if the ratio is <1.00, Stableo is under-collateralized and redemptions might be at risk or halted. When the collateral ratio drops below 100%, the ReserveVerifier locks out new minting operations. It sends a signal to the MintController, preventing new €O tokens from being created until the system is fully collateralized again. This enforcement happens autonomously, without manual intervention, making it a vital safeguard. Halted actions are queued to ensure guaranteed delivery and automatic retry policy is in place. After 5 retry attempts the action is denied. Queue processing can be executed with a sleep timer to avoid sudden spikes. Additionally, ReserveVerifier can reduce minting caps proportionally if the ratio approaches a lower boundary or emit warning events to governance and DAO channels.

This contract is the enforcement engine of Stableo's transparency promise, ensuring every token is backed and every operation is trustlessly verified.

5. RedemptionMonitorContract

The RedemptionMonitorContract is a real-time watchdog mechanism designed to monitor system stress and trigger automatic protections if abnormal redemption or oracle behavior is detected. It functions as the system's early warning and circuit breaker logic.

RedemptionMonitorContract compares the total circulating supply of €O tokens to the immediately redeemable liquidity (e.g., fiat + ultra-short-term bonds) and ensures that there is sufficient liquidity to meet redemptions without triggering a reserve crisis: $Liquidity\ coverage\ ratio\ (LCR)\ =\ \frac{Fiat + Short\text{−}term\ maturities}{Outstanding\ €O\ supply}$. If the ratio falls below a predefined threshold, the contract flags it. Functionality delivers frequency, volume and origin of redemption requests. It analyzes redemption patterns both in time and volume that flags high frequency of requests that could indicate panic or attack and create alerts in the off-chain dashboard as well abnormally large redemptions are flagged.

Origin tracking includes:

- Wallet distribution of redemptions (e.g., whale concentration).
- Geography, when integrated with off-chain monitoring (e.g., sanctioned regions or IP alerts).
- Time-of-day clustering.

This builds a statistical baseline (μ and σ of redemptions) against which anomalies are measured. Any deviations from the baseline triggers smart contract circuit breakers in any of the following situation ensuring automatic, rapid protection without governance delays:

- Sudden surge in redemptions (exceeding daily moving average) defined as:

$$R_t > \mu_R + k \cdot \sigma_R$$

  Where:

  - R_t = Current redemption request
  - μ_R = Historical mean (e.g., 24h average)
    σ_R = Standard deviation
  - k = Sensitivity factor (3 or 4)

- NAV deviation over 1% in <24 hours. If Net Asset Value changes by more than 1% (up or down) in a short window, it may indicate price shocks, custodial misreporting, or mispriced assets. Deviation is detected comparing NAV_{now} to NAV_{24h}.

- Oracle data delay or suspected manipulation. If data updates from any oracle (Bond, Custody, or Fiat) are missing or contain:
  - Stale timestamps
  - Divergent values beyond $\delta \cdot \overline{P}$ thresholds
  - Invalid or unverifiable signatures

The fallback logic is activated, and oracle feeds are assumed unreliable. The status variable is publicly emitted in machine-readable status representing system's operational mode:

- NORMAL = System is operating smoothly. All checks are green.
- DEGRADED = One or more soft triggers activated. Redemptions allowed, minting paused.
- HALTED = Critical trigger activated. Minting and redemptions paused immediately.

This status is consumed by other contracts (e.g. *MintController*, *RedemptionRouter*) and apps ensuring end-to-end redemption surveillance (detecting panic, systemic risk, or liquidity depletion), oracle health checking (preventing consumption and/or operation on outdated or tampered data), real-time circuit breaking (automatically initiating safety mode without delay) and ensuring transparent status output providing system-wide visibility into health and response mechanisms, pausing certain functionalities, informing users and governance of the issue as well as partial or full payload logging data for audit trails protecting both users and reserve integrity under high-stress scenarios.

6. CircuitBreakerContract

The CircuitBreakerContract serves as the final line of defense in the €O system as an emergency mechanism designed to automatically pause minting and redemption activity in the event of severe market anomalies, data inconsistencies, or liquidity shocks. It prevents systemic failures and allows the system to stabilize before resuming normal operations.

Circuit breaker acts as a last-resort failsafe, enforcing transaction halts by freezing minting and redemptions across the system when extreme conditions are detected. It is automated for speed but can also be overridden (or later resumed) by governance or automated cooldown logic protecting users from entering/exiting at mispriced valuations or during illiquid phases. The contract listens to multiple upstream signals to decide when to activate the halt:

- Deviation from expected bond price bands. If any bond's reported price deviates too far from its expected market range (based on historical pricing, TWAP, or predefined spreads) and prevents manipulation or pricing errors from affecting NAV or user transactions:

$$|P_i - \overline{P}| < \delta \cdot \overline{P}$$

  - P_i = current price of bond i
  - $\overline{P}$ = average price of the last N days
  - σ_P acceptable price deviation (1%-2%)

- Signals from the upstream *RedemptionMonitorContract* are inherited and actions defined for statuses ensuring coordination across monitoring and execution layers:
  - DEGRADED = Circuit breaker may activate depending on severity or duration.
  - HALTED = Circuit breaker triggers immediately, regardless of other conditions.
- Measured if rolling volatility of bond prices from *BondPriceOracle* exceeds the threshold using $\sigma_{30d} = StdDev(P_{t-30d},..., P_t)$. A volatility spike is often a precursor to pricing errors or extreme redemption behavior. If volatility surpasses a max threshold (3% over 30 days), signals instability or market panic.

Once triggered the circuit breaker pauses mint/redemption endpoints. All smart contract functions for minting new €O or redeeming €O for fiat or bonds are disabled. This ensures users cannot interact at unfair, manipulated, or dangerous valuations. Trigger also logs the exact reason the halt was triggered (e.g., "Volatility Breach", "Oracle Stale", "NAV Shock") together with recording on-chain timestamp for transparency and postmortem auditing. And allowing future queries for UX and governance reporting (frontend, analytics dashboards, BI reporting tools). The triggered pause can only be lifted by governance or automated cooldown recovery logic:

- Manual reset by governance:
  - For extreme events requiring human review.
  - Governance multisig or DAO vote can resume operations after analysis and audit.
- Automated cooldown:
  - If all metrics return to acceptable range for a fixed period (e.g., 24h of stable NAV, oracle uptime, and redemptions) circuit breaker automatically lifts halt and resumes operations.
  - Ensures safety without bottlenecking operations if the event resolves naturally.

The CircuitBreakerContract in turn is the contract system's equivalent of an “emergency switch” - automated, secure, and designed to maintain user trust and solvency in the face of black swan events or cascading failures.

- Edge-Case handling
  - If oracle feeds fail permanently:
    - Switch to secondary (fallback) oracle source if available.
    - Trigger on-chain pause (HALTED state) if no feed recovers within 2 hours.
    - Notify governance for manual override.
  - If custodian attestations delay:
    - Mark reserves as “PENDING” after 24 hours.
    - Apply graduated discount factor to NAV until attestation arrives.
  - All failures/edge cases must be traced by monitoring and alerting and handled by the governance. Automatic fall-back options should be set in place or manual solutions for extreme cases.

Phase 2 improvements

- Correlation-based Stress tests to evaluate how bond prices and redemption flows correlate in extreme events using copulas or tail risk models.
- Dynamic parameters used iInstead of static δ, k, or μ, can be derived dynamically using EWMA or regime-switching models.
- Liquidity tiering tagging bonds with L1 (instantly liquid), L2 (1–3 day sale), L3 (illiquid) and prioritizing redemptions accordingly.
- Adjustment of NAV discounts based on tier-level liquidity.
- Reinforcement learning agent that continuously tunes k, δ, μ thresholds to minimize redemption stress and optimize spread.

Security & Safety measures

To ensure data integrity and resilience against manipulation or insider risk, the oracle system is designed around several critical defense layers that encompass cryptographic access control, fail-safes and transparency guarantees.

- Whitelisted Public key infrastructure. Only pre-approved, whitelisted public keys (registered on-chain) are authorized to submit oracle data. These keys are assigned to trusted, KYC-compliant oracle providers (e.g., financial institutions, bond market aggregators), and are strictly access-controlled. This ensures that rogue entities cannot inject false data into the system.
- HSM-Protected signing keys. All off-chain oracles must sign their updates using keys stored in Hardware Security Modules (HSMs) to protect against key theft, malware attacks and internal misuse. These are tamper-resistant devices certified under standards such as FIPS 140-2 or Common Criteria. HSMs provide:
    - Physical and cryptographic isolation
    - Enforced key usage policies
    - Audit logs of signing activity
- Rate limiting. Each oracle contract enforces a maximum update frequency (1 update/hour). This constraint reduces the surface for manipulation via spamming updates and ensures consistency across distributed data providers. It also stabilizes gas usage and operational costs.
- TWAP smoothing. All oracle values undergo Time-Weighted Average Price (TWAP) smoothing before being posted on-chain. This mechanism calculates a rolling average over a defined interval (30 minutes) to:
    - Mitigate short-term volatility
    - Resist flash loan-based manipulation
    - Dampen sudden spikes from low-liquidity events
- Fallback trigger conditions. The system enters a fallback state disabling redemptions or pausing certain actions if any of the following occur (fallback mode prompts the *CircuitBreakerContract* to switch to HALTED or DEGRADED state, preventing exploitation):

    - No update received within a defined interval >6 hours)
    - Signature verification fails (non-matching or expired)
    - Value anomalies beyond statistical deviation thresholds (3σ outlier)
    - Conflicting data across sources (price divergence >1%)
- Multi-source validation. All bond prices are derived from at least three independent data providers (e.g., Bloomberg BVAL, Refinitiv, Euroclear). Prices are normalized and subjected to outlier rejection and median filtering. This prevents spoofing through any single compromised feed and increases robustness.
- Auditability via emitted logs. Every oracle update emits an on-chain event log that serves as an immutable audit trail for verifying oracle performance, supports data for post-incident reviews and regulatory compliance reporting. Each log entry includes:
    - Price/portfolio change
    - Timestamp
    - Signer ID
    - Merkle root and data hash hybrid

This architecture treats oracles not just as passive data providers but as critical infrastructure. With cryptographic identity, HSM protection, statistical smoothing, multi-source validation, and strong audit trails, the system minimizes attack vectors and ensures high-integrity input to the stablecoin protocol.

Governance proposals for upgrades

As with any system that must balance security, decentralization, and regulatory compliance, governance processes are structured with checks, balances, and time delays to ensure safe evolution over time. A multi-signature-controlled DAO governs the system, composed of diverse stakeholders (foundational developers, institutional partners (e.g., custodians), community delegates and compliance officers). This ensures that no single entity can act unilaterally, aligning with best practices in DeFi governance and institutional-grade security a Three-Phase Upgrade Lifecycle is introduced.

1. Proposal phase

A governance participant (e.g., protocol developer, third-party oracle provider) submits a detailed upgrade proposal. These can include:

- New oracle data feeds (e.g., integrating RedStone or Chainlink)
- Updated rate limits
- Rotation of oracle signing keys
- Upgrades to logic (e.g., better smoothing algorithm)
- Circuit breaker threshold updates

Each proposal must include rationale, technical specifications, potential risks, and audit status.

2. Voting phase

Token holders or governance delegates vote using snapshot-based or on-chain mechanisms. Each vote has:

- A required quorum (minimum number of voters)
- A threshold (e.g., 66% approval) for passing
- Optional weighting based on stake or reputation

3. Timelock execution

Once approved, a timelock (e.g., 72 hours) delays execution. This:

- Prevents flash governance attacks
- Gives time for community intervention if a malicious proposal is passed
- Allows off-chain actors to prepare infrastructure or legal responses

Only after the delay does the proposal execute automatically (or with multi-sig approval).

4. Wallet-specific limits

While system-wide thresholds protect against macro risks, they don't address micro-level abuse such as multi-wallet Sybil attacks, whale-induced liquidity shocks, or unverified wallet flooding during redemptions. To manage this, you should implement wallet-specific redemption caps and behavior tracking mechanisms that scale with user verification status, activity history, and behavior patterns. This aligns well with MiCAR compliance, ensures equity in access, and supports anti-abuse protections (particularly relevant in B2C use cases like payroll, remittances, or small-business accounts). Assuming:

- R_t^{wallet} = redemption volume from a specific wallet during period t.
- C^{tier} = maximum cap based on KYC tier (e.g., Tier 1, Tier 2).
- $f^{penalty}$ = a factor applied for suspicious activity (e.g., bot heuristics).
- L_t^{wallet} = adjusted per-wallet limit at time t.

$$L_t^{wallet} = C^{tier} \cdot f^{penalty}$$

Trigger individual wallet throttle if:

$$R_t^{wallet} > L_t^{wallet}$$

KYC-based caps:

- Tier 0 (anonymous): €500/day
- Tier 1 (basic KYC): €5,000/day
- Tier 2 (verified): €25,000/day
- Tier 3 (institutional): unlimited but rate-limited

Bot detection heuristics:

- Monitor repeated redemptions with same amount and timing
- Detect unusual gas price patterns
- Flag wallets that switch IPs, gas patterns, or are funded by mixers

Dynamic adjustment:

- During stress, caps can auto-scale down by governance or protocol rule
- Cooldown periods (e.g., T+1 for flagged wallets)

Key examples of governance actions:

- Adding new price feeds for higher redundancy (e.g., multiple BVAL endpoints or Euroclear access)
- Adjusting fallback thresholds to respond to volatility spikes
- Rotating cryptographic keys in the event of an HSM breach or provider exit
- Upgrading smart contract logic, with external audit and back-test evidence
- Changing mint/redemption behavior, e.g., stricter rules during financial crisis simulations

Each of these actions strengthens protocol resilience while adapting to market changes. Governance ensures that upgrades are deliberate, safe, and community-reviewed. By enforcing a structured proposal-vote-delay cycle, combined with role-based permissions and verifiable audit trails, the system supports innovation without compromising user trust or security. It mirrors regulatory processes in TradFi (e.g., ISO change approvals or central bank policy updates), combining that rigor with the transparency of DeFi.

As the oracle layer becomes more complex, the governance process must also evolve to handle multiple aspects of system lifecycle, like:

- Higher stakes for errors. With increased automation (e.g., redemptions or halts triggered by price deviations), the consequences of a faulty or manipulated oracle feed are more severe. Governance must impose stricter voting thresholds, require audits, and introduce proposal templates with quantitative backtesting.
- More specialized proposals. Upgrades may require multiple simultaneous contract upgrades (e.g., BondPriceOracle + ReserveVerifier + RedemptionMonitorContract). This creates a need for multi-contract upgrade bundles and a composable governance framework.

- Timelock expansion or Override mechanisms. Some upgrades (e.g., to fix a price anomaly during a bond market shock) may need emergency execution paths with shorter timelocks but extra approval (e.g., 4-of-5 multisig + community review).
- Audit tags and Transparency layers. Governance proposals increasingly include on-chain metadata, such as:
    - Audit hash references
    - Version tags
    - Change diffs
    - Expiration logic for keys
- Meta-governance for oracle providers. The decentralized autonomous organization (DAO) must also govern who can become an oracle provider, leading to reputation staking, KYC/KYB[11] whitelisting, and performance score tracking.
- The governance system must become more modular, rigorous, and automated ensuring that as oracles gain power and complexity, the social and technical controls around them remain strong, transparent, and accountable.

3.3 Tokenization & Issuance layer

The Stableo token (symbol: €O) is a permissionless, euro-pegged, ERC-20[12] compliant stablecoin with deterministic backing, embedded regulatory enforcement, and programmable compliance.

- 1:1 Redemption guarantee: each €O token is fully collateralized by €1 worth of sovereign euro bonds, adjusted daily through an automated reserve oracle.
- Minting mechanism: in the initial phase authorized counterparties (including fintechs, licensed virtual asset service providers (VASPs), and institutional funds) can mint €O by depositing euros via a partnered Electronic Money Institution (EMI), which facilitates fiat custody and transaction settlement on behalf of the protocol.
- KYC[13]/AML[14] compliant gateways: all mints and burns pass through on/off-ramps equipped with embedded AML transaction screening and wallet risk scoring.
- Smart contract issuance: The token is issued by a verified smart contract with built-in freeze/blacklist logic per MiCAR and FATF[15] guidance, enabling SafeFi (Safe Finance) capabilities.

Unlike current *euro* stablecoins, Stableo's issuance mechanism integrates real-world banking interfaces and on-chain settlement through a unified infrastructure.

[11] KYB - Know Your Business - refers to the process of verifying the business (companies, their owners, and legal status).
[12] ERC-20: This stands for Ethereum Request for Comment 20. It's a technical standard used for smart contracts on the Ethereum blockchain for implementing fungible tokens. This means that all tokens created under this standard are interchangeable and have the same value.
[13] KYC - Know Your Customer - refers to the process of verifying the identity of clients, typically for financial institutions, to assess their suitability and potential risks of illegal intentions for the business relationship.
[14] Anti-Money Laundering. It refers to a set of regulations and procedures designed to prevent criminals from disguising illegally obtained funds as legitimate income.
[15] Financial Action Task Force. It's an intergovernmental organization founded in 1989 on the initiative of the G7 to develop policies to combat money laundering and terrorist financing.

Token characteristics and Financial guarantees

Token Symbol: €O
Standard: ERC-20 compliant, EIP-2612 permit-enabled
Backing: Fully backed by sovereign euro-denominated bonds (short-term, investment-grade)
Redemption guarantee: 1 €O = €1 collateral value (NAV-based, adjusted daily)
Freeze & Blacklist capabilities: Enabled per MiCAR and FATF Travel Rule guidelines

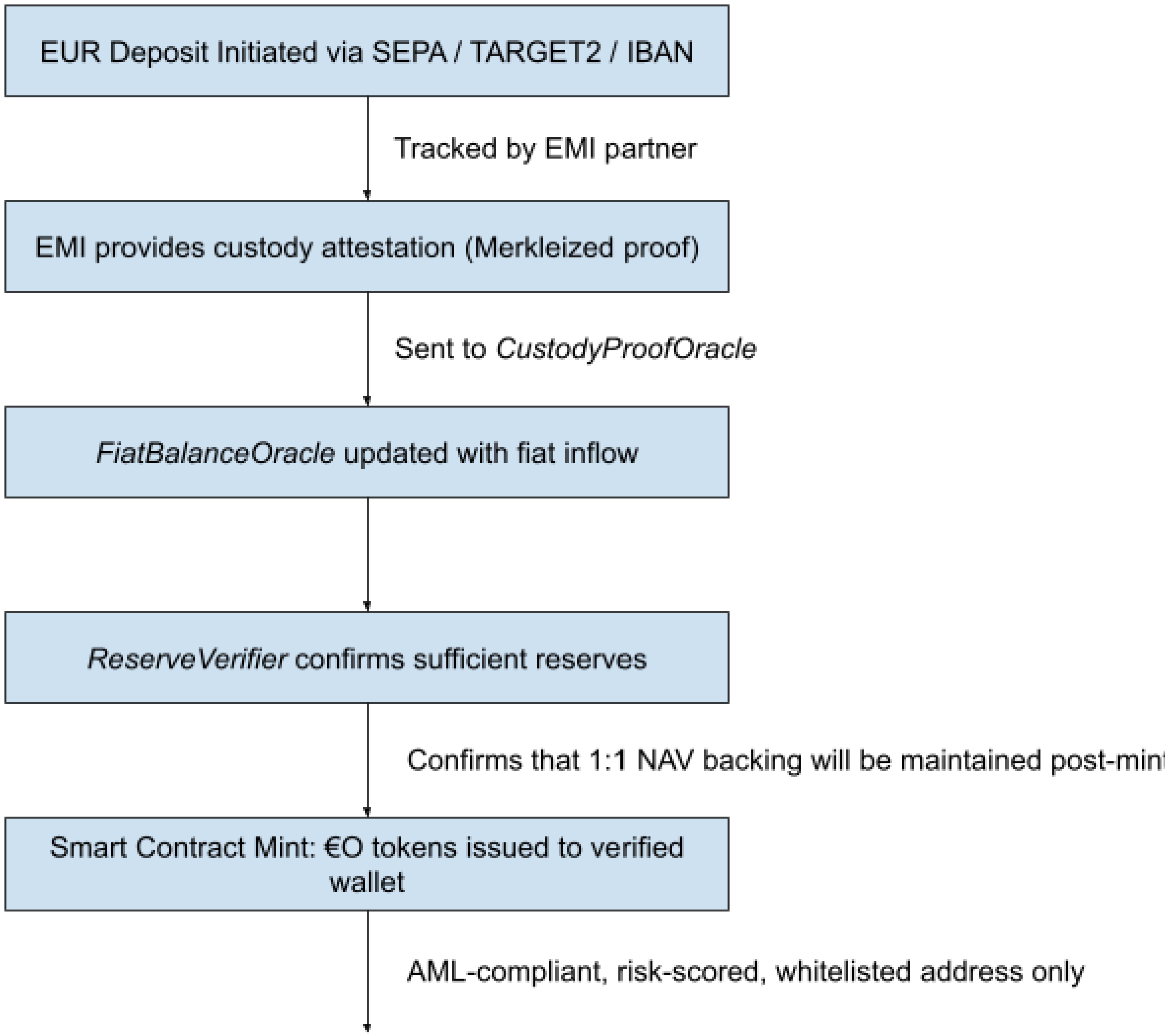
Financial mechanism explanation: each €O token minted is underpinned by a deterministic accounting mechanism ensuring that exactly €1 worth of assets (valued via the *ReserveVerifier* and *BondPriceOracle*) is held in custody. These assets consist primarily of sovereign bonds structured for liquidity and price stability.

Accounting identity: $Total\ €O\ Supply\ =\ \frac{Total\ NAV\ of\ bond\ reserves + Fiat\ balances}{1}$

Minting mechanism – Off-chain to On-chain bridging

Participants (Phase 1):

- Licensed VASPs
- Regulated fintech firms
- Institutional investors/funds



Smart contract Safety features:

- KYC/AML enforced by gateway APIs and signature verification
- Only approved mints via registered EMI rails
- Blacklist logic triggered via governance or compliance triggers

Security model:

- Multi-sig control for issuance contract updates
- Rate-limiting of mint frequency per address
- Emit logs and compliance audit trails at every mint/burn event

3.4. Bond purchase & Laddering strategy – Financial optimization layer

Execution strategy

The section outlines the execution methodology for the purchase, allocation, and management of bond assets that back the Stableo €O token. The strategy is designed to optimize capital preservation, ensure timely redemptions and comply with liquidity, risk, and transparency obligations under MiCAR.

Execution objectives:

Stableo's bond execution strategy is driven by five primary financial and operational goals:

1. Redemption liquidity: Ensure that reserves are structured to meet redemption flows without needing emergency liquidation.
2. Capital stability: Invest exclusively in low-risk euro-denominated sovereign bonds from AAA/AA-rated EU countries or EU supranationals (e.g. EIB, ESM).
3. Low transaction cost: Minimize bid-ask slippage via timing, volume aggregation, and optimal execution routing.
4. Transparent valuation: Ensure all instruments allow for daily mark-to-market pricing to maintain accurate NAV calculation.
5. MiCAR Compliance: Meet asset-backing, liquidity, and transparency rules for ARTs (Asset-Referenced Tokens).

Execution methodology:

Stableo does not rely on real-time bond trading to fulfill redemptions. Given the inherent latency and settlement cycles in bond markets (typically T+1 or T+2), redemptions are instead fulfilled using scheduled batch operations. Schedules can be changed as per market conditions and development phase, but must maintain a balance between costs and bond yield maximization. In the MVP stage, bond trades will be executed manually once per week, with a treasury operator adjusting the ladder based on inflows/outflows. Post-MVP, this will evolve into semi-automated or smart contract-controlled batch execution, with 1–3 rebalancing events per week, based on liquidity thresholds and redemption volumes. This approach noticeably reduces gas costs and slippage and avoids forced liquidation risks during holidays or illiquid markets. As an added bonus this allows bond aggregation, improving execution price and in case of major demand cash reserves are available.

In scenarios where redemption surges are suspected to be adversarial or economically irrational (e.g., Sybil-style multi-wallet drains), governance may temporarily waive mint/redemption fees for high-volume wallets flagged as triggering circuit breakers. This makes repeated exploit attempts prohibitively expensive, as attackers would incur real fiat costs without being able to recycle funds via minting. Such fee suppression acts as an economic rate limiter, ensuring that only users with genuine intent can afford sustained activity during throttled redemption windows. This approach makes economic DoS attacks unprofitable by forcing real fiat costs per attack cycle. It respects decentralization as governance or oracles must flag behavior, not Stableo operators allowing to engage smart contract throttle modes - restrictions or conditional fee logic (e.g., fees based on wallet score or history).

Bond selection criteria

- Issuer Type: Strictly limited to EU sovereigns and EU-based supranationals (e.g., Germany, France, EIB, ESM). *U.S. Treasuries and non-EU instruments are excluded.*
- Credit Rating: Minimum AA- as per S&P/Fitch or equivalent from another major CRA.
- Currency: Only EUR-denominated bonds are permitted to avoid FX mismatch risk.
- Instrument Type: Fixed-income securities with:
    - High liquidity on EU trading venues
    - Daily price discovery (e.g., listed on Tradeweb, Euroclear)
    - No embedded options or convertibility features

Laddered bond tranche framework

Stableo uses a rolling bond ladder to structure maturities such that liquidity becomes available continuously without forced sales. Stableo does not rely on real-time bond trading to fulfill redemptions. Given the inherent latency and settlement cycles in bond markets (typically T+1 or T+2), redemptions are instead fulfilled using scheduled batch operations.

In the MVP stage, bond trades will be executed manually once per week, with a treasury operator adjusting the ladder based on inflows/outflows. Post-MVP, this will evolve into semi-automated or smart contract-controlled batch execution, with 1–3 rebalancing events per week, based on liquidity thresholds and redemption volumes. This approach reduces gas costs and slippage, and avoids forced liquidation risks during holidays or illiquid markets together with bond aggregation, improving execution price.

Bonds are allocated into staggered tranches to align with anticipated redemption intervals: 2 weeks, 4 weeks, 8 weeks, 12 weeks, 6 months, 1 year. Each tranche is limited to a maximum 20% of NAV to mitigate maturity clustering and rollover risk. Bonds are selected so that a tranche matures regularly, providing a natural liquidity release to match redemptions resulting in bonds maturing regularly which matches the redemption demands.

Tranche	**Maturity**	**% of NAV cap**
T1	2 weeks	10%
T2	4 weeks	10%
T3	8 weeks	20%
T4	12 weeks	20%

T5	≤6 months	20%
T6	≤1 year	20%

- T1–T4 (2 to 12 weeks): Short-term tranches offering high liquidity and rolling redemption coverage.
- T5 (≤6 months): Slightly longer instruments to capture higher yields without locking capital excessively.
- T6 (≤1 year): Optional long-end of the ladder to boost returns during rate stability periods, while still aligned with low-duration risk.

This distribution provides a consistent maturity stream every few weeks, diversity of duration for yield optimization and 20% redemptions possible per month at minimum, backed by maturing bonds. The weekly or biweekly maturities match redemption cycles and allow for organic release of liquidity while caps on each tranche prevent excessive clustering that could cause rollover stress. Bonds near maturity can be prioritized for sale if early redemption demand exceeds laddered maturities.

- Monitors fiat inflows and timing via EMI
- Aggregates capital for batched execution
- Connects to venues: Euroclear, Tradeweb, Interbank platforms
- Executes using VWAP (Volume-Weighted Average Price) to minimize slippage

Bond Scoring Formula

$$\beta_t = \left(\frac{D_t}{M_t}\right) \cdot (1 - S_t) \cdot \left(\frac{L_t}{R_t}\right)$$

Where:

- D_t = Duration penalty weight (penalizes longer duration bonds)
- M_t = Time to maturity (days, favoring shorter-term bonds)
- S_t = Spread to par (penalizes premium bonds, lower is better)
- L_t = Fit coefficient to target tranche ladder (penalizes oversaturated tranches)
- R_t = Forecasted redemption pressure (forward-looking, higher stress increases penalty)

Calibration & Optimization pipeline

1. Data collection
   a. 10+ years of sovereign bond data
   b. Credit ratings, prices, spreads, maturities, and daily liquidity.
   c. Normalization for monetary regime changes (e.g., pre- vs. post-NIRP).

2. Back-testing framework
    a. Computation bond scores β_t for historical snapshots.
    b. Portfolio ranking using these scores simulating forward 30–180 day returns.
    c. Ranking evaluation efficacy using:
        i. Sharpe Ratio
        ii. Max Drawdown
        iii. Volatility
        iv. Tracking error vs. benchmarks

3. Weight Optimization

$$\beta_t = \left(\frac{D_t^{\alpha}}{M_t^{\gamma}}\right) \cdot \left(1 - S_t^{\delta}\right) \cdot \left(\frac{L_t^{\lambda}}{R_t^{\rho}}\right)$$

Where:

- β_t = Composite bond desirability score at time t
- D_t = Duration (longer bonds may carry more interest rate risk)
- M_t = Time to maturity (shorter maturities preferred for liquidity)
- S_t = Spread to par (distance from face value — premiums are penalized)
- L_t = Liquidity fit coefficient (how well the bond matches target ladder buckets)
- R_t = Redemption pressure forecast (expected liquidity need over horizon)
- $\alpha, \gamma, \delta, \lambda, \rho$ = Tunable weights/exponents to control the influence of each term

This formula introduces exponent-based weighting to fine-tune how each input influences the bond selection score. For example, if longer duration is more dangerous under current macro conditions (e.g., rate hikes), the model can increase α to penalize duration more heavily. Conversely, if liquidity alignment is more important, λ can be boosted. By tuning these exponents using historical performance data, Stableo can learn which features predict bond stability or efficiency under various market regimes.

- A higher ρ penalizes long-term holdings when redemption stress is forecasted.
- A lower δ reduces the spread-to-par penalty, allowing some premium bonds.
- A balanced γ allows gradual scaling with maturity instead of binary inclusion/exclusion.

These parameters are optimized using a grid search or Bayesian optimization, targeting maximum Sharpe ratio or minimum drawdown on simulated historical portfolios. Penalty terms (L2 norm or entropy constraints) are included in the loss function to prevent overfitting and maintain generalizability.

4. Transformation of Inputs. Before scoring, inputs are transformed to ensure mathematical stability and resistance to outlier distortion. Log-scaling and quantile normalization is

applied: $log(1 + D_t), log(1 + L_t)$. Duration and liquidity distributions are often right-skewed, meaning a few large values can dominate scoring. Log-scaling compresses this variance, making weights more stable and interpretable. Additionally the redemption pressure is normalized: $R_t^{normalized} = Quantile(R_t)$. Redemption pressure is scenario-dependent and may spike unpredictably (e.g., during crises). Applying quantile transformation converts raw values into percentile ranks (e.g., 0.95 for a top 5% event), giving the model a more reliable signal across timeframes. These transformations are critical for making the scoring model statistically robust. They eliminate distortions from large absolute numbers and allow scoring to be compared across bond types, regimes, and currencies. Without these steps, the model may overweight liquidity-heavy sovereigns or ignore subtle but important signals like redemption clustering.

5. Combined with exponent weighting, these transformations allow Stableo to build a dynamic, governance-adjustable scoring model that ranks bonds by fitness under real-time liquidity and macro conditions — forming the core of the bond ladder allocation strategy.
6. Validation & Robustness
    a. K-fold cross-validation across different historical windows (e.g., 2012 debt crisis, 2020 COVID).
    b. Stress test scoring during known volatility regimes.
7. Governance Documentation treating each variable's exponent or coefficient as tunable.

Interpretation: Bonds with highest score provide the optimal tradeoff between liquidity, price, and strategic fit. The bond scoring formula is a custom, multi-factor evaluation mechanism designed to optimize bond selection in a laddered reserve strategy. This formula doesn't aim to maximize yield alone, but it balances liquidity, pricing discipline, redemption planning, and tranche diversification. Each variable plays a specific role in simulating tradeoffs seen in treasury operations and fund liquidity planning. The core logic reflects practices from traditional asset-liability management (ALM), particularly in stablecoin or money market fund structures where liquidity predictability is as important as return.

In this framework:

- A higher D_t (duration penalty weight) increases the numerator but is offset by longer M_t (maturity), discouraging long-dated bonds.
- The $(1 - S_t)$ term rewards bonds priced at or below par (discounts), avoiding premium bonds that could erode NAV on redemption.
- The L_t term promotes distribution across the bond ladder, reducing overconcentration in specific tranches. For instance, if the 8-week tranche is nearing its 20% NAV cap, L_t for that category would decline, pushing the engine toward underfilled tranches like 12-week or 6-month maturities.

- The R_t factor embeds a forward-looking redemption pressure coefficient, forecasting the likely stress in upcoming weeks. If on-chain withdrawal intent signals suggest a higher redemption rate, bonds with earlier maturity or higher liquidity get prioritized.

Suppose there are two candidate bonds:

- Bond A: 30-day maturity, priced at 99.8 (close to par), in an underfilled tranche (T3), and facing low redemption pressure.
- Bond B: 90-day maturity, priced at 101.5 (above par), in an already full tranche, during a period of high redemption.

Despite Bond B having a slightly higher nominal yield, Bond A would likely produce a higher β_t score due to its lower premium, better liquidity fit, and favorable tranche availability. This kind of scoring allows the protocol to act like a disciplined institutional fund manager as it doesn't chase returns at the expense of liquidity, regulatory alignment, or user redemption capacity. This system is inspired by liquidity-weighted laddering seen in treasury ETFs and euro short-term investment funds (e.g., ESMA-compliant low-duration bond funds), ensuring that the €O token remains safely redeemable and financially transparent.

Off-chain execution agent

- Connects to venues like Euroclear, Tradeweb, and Interbank dealer networks
- Aggregates fiat inflows from EMI partner
- Executes batched bond purchases every 2 weeks for efficiency and better pricing

Execution rules

- Market Hours: 09:00–17:00 CET only
- VWAP Targeting: Orders target the Volume Weighted Average Price to minimize price impact
- Max Deviation from Mid: ±0.5% threshold
- Min Lot Size: €100,000
- Approved Venues: Only EU-regulated MTFs, RMs, or brokers
- Counterparty Controls: Whitelisted EU-based financial institutions only MiCAR

Sample bond redemption model. Assuming a 4% liquidity buffer on €100M AUM = €4M in cash reserves, the treasury can withstand up to 2 days of heavy redemptions before requiring bond liquidation[16]. Liquidity monitoring logic (see Oracles section) determines when bond sales are triggered. Government bonds, especially Eurozone short-dated bills, may not be available for same-day liquidation. Redemption batching aligns with market norms and prevents yield leakage from over-trading.

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[16] Government bonds, especially Eurozone short-dated bills, may not be available for same-day liquidation. Redemption batching aligns with market norms and prevents yield leakage from over-trading.

Scenario	Redemptions/day	Cash buffer needed	Bond sell frequency
Low Activity	€0.5M	€1.5M (3 days buffer)	Weekly
Medium Activity	€2M	€6M	2× per week
High Activity (stress)	€5M+	€10M	Daily

Liquidity & Redemption buffer strategy

- Liquidity buffer: Minimum 10% of NAV is held in near-cash instruments (e.g., EU sovereign T-bills with ≤2-week maturity)
- Weekly maturity events: Laddering ensures a portion of bonds mature every week to replenish liquidity
- Redemption order of Operations:
    1. Use fiat buffer
    2. Use maturing bonds
    3. Sell shortest-maturity tranche on secondary market (if needed)

Forecasting inflows/Outflows

A rolling forecast model compares average weekly inflows (mint deposits) and outflows (redemptions):

$$\Delta L = \sum_{i=1}^{n} (I_i - O_i)$$

Where:

- I_i = Inflows
- O_i = Outflows

If projected net outflows exceed liquidity buffer + maturing tranches, preemptive sale of longer bonds is queued. The rolling liquidity forecast model serves as a foundational risk management tool in the Stableo protocol, helping the off-chain execution engine anticipate whether future liquidity demands can be met without disrupting NAV or breaching redemption guarantees. In this equation, I_i represents weekly fiat inflows (mints), and O_i represents weekly outflows (redemptions). By aggregating these over a chosen rolling window (e.g., 4 or 8 weeks), the model calculates net liquidity movement (ΔL), allowing the protocol to understand if liquidity is growing or depleting.

This approach mirrors traditional cash flow forecasting used by treasury desks in banks and money market funds. When ΔL is negative and trending downward, it signals that redemptions are outpacing new deposits, triggering defensive portfolio actions. If the forecasted outflows exceed the combination of the current liquidity buffer and upcoming bond maturities (short-term tranches like 2–8 weeks), the protocol prepares to preemptively sell longer-duration bonds (e.g., 12 weeks or 6 months). This ensures that sufficient fiat is available on-chain to meet redemptions, maintaining the 1:1 redemption guarantee and avoiding forced liquidation during stressed market conditions, which could otherwise introduce slippage or NAV erosion.

For example, suppose the average inflows over 4 weeks are €500,000/week, while redemptions rise to €750,000/week. A projected deficit of €250,000/week would accumulate to €1 million over a month. If the liquidity buffer is only €600,000 and the maturing bonds cover just another €200,000, the remaining €200,000 gap would need to be filled through proactive bond liquidation. This forecast thus directly informs execution strategy, enabling predictive liquidity management. It's a critical safeguard in environments where market sentiment or macroeconomic events (e.g., ECB rate shifts, regulatory announcements) could cause sudden user behavior shifts.

Overall, this rolling model represents a conservative, data-driven liquidity framework that blends well with decentralized transparency and centralized execution. It enables Stableo to meet redemptions under duress while minimizing portfolio disruption — a hallmark of modern digital cash systems aiming to achieve both stability and capital efficiency.

Governance parameters:

- All variables are governance-modifiable
- Governance may also blacklist bonds or counterparties
- Emergency override possible in volatile market scenarios
- Execution logs and NAV impact reviewed by the Risk & Accounting function
- Automated Alerts:
    - Failure to execute
    - Ladder imbalance
    - Liquidity breach
- Monthly rebalancing adjusts ladder allocations based on:
    - Redemption pattern shifts
    - Interest rate changes
    - Bond yield curve dynamics

Fallback protocols

If market conditions degrade:

- Switch to Manual Mode: Execution controlled by the governance
- Increase Fiat Buffer: From 10% to 20%; to cushion redemptions
- Token holders notified via on-chain message and public porta
- Circuit breaker hooks throttles redemptions if NAV deviation exceeds 1%

This bond acquisition and laddering strategy sits at the core of Stableo's financial resilience. By combining near-cash reserves, systematic laddering, and quantitative bond selection, the system ensures:

- Predictable and sustainable redemption capacity
- High transparency through daily pricing and execution audit logs
- Minimal market risk due to conservative instruments and tight duration control
- Full alignment with MiCAR and SafeFi best practices

The combined financial, algorithmic, and governance safeguards provide a durable architecture for the €O token's long-term credibility and safety.

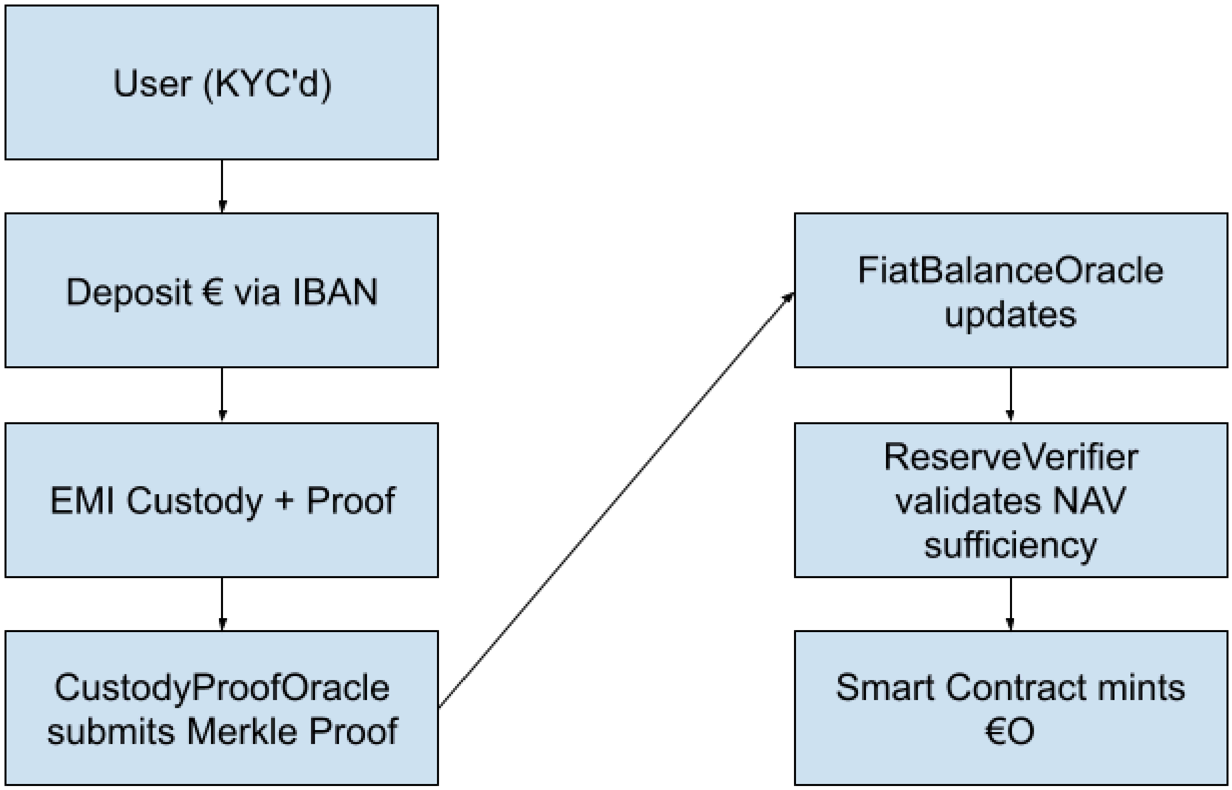
3.5 Minting & bond execution flow

This section outlines the functional and technical architecture that underpins the issuance of €O tokens backed by euro-denominated government bonds of EU member states. The processes are designed to comply with Regulation MiCAR and other legal acts applicable in Latvia. These flows ensure full collateralization, operational resilience, KYC/AML compliance and auditability, meeting supervisory expectations of Latvijas Banka.

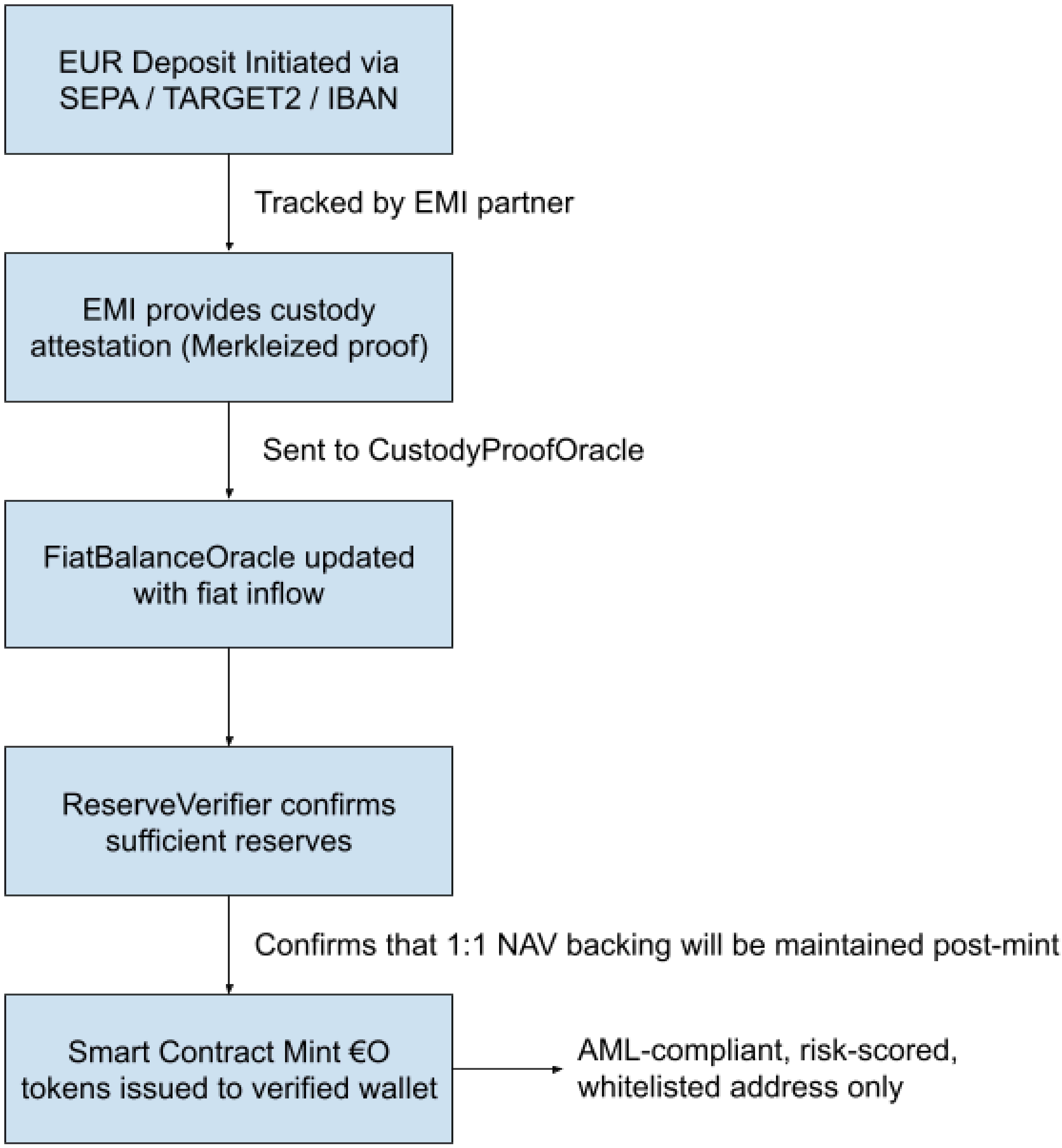
3.5.1 Token minting flow

The €O token is minted on-chain through a tightly controlled, compliance-first process. Issuance is triggered only upon verified fiat deposits and reserve sufficiency checks. Stableo mints and redeems tokens via licensed Electronic Money Institutions (EMIs) or banking partners that handle fiat deposits and withdrawals. These institutions offer connectivity to Euro-area real-time payment networks. Stableo does not operate its own banking rails or require users to interact with SEPA/TIPS directly. Instead, the platform integrates with partners offering the lowest-latency and lowest-cost routing per user geography and account type. All redemptions are matched with treasury-side token burns, ensuring 1:1 collateralization at the time of fiat settlement. Redemptions may be batched and executed during market hours (to match bond ladder sales, etc.). For later phases customer segmentation can be implemented to handle appropriate mint/redeeming streams:

User type	Fiat partner
Retail (< €10K)	EMI
SME / Treasury	EMI, Banking partner
Institutional (>€1M)	Custody bank



- A verified user (KYC/KYB-compliant) deposits euros into a segregated IBAN at a licensed Electronic Money Institution (EMI).
- The EMI generates a digital custody confirmation, submitted to a CustodyProofOracle on-chain as a Merkle proof.
- The FiatBalanceOracle updates the total fiat position available for backing.
- The ReserveVerifier validates the Net Asset Value (NAV) of reserves and ensures compliance with buffer thresholds.
- If conditions are met, the smart contract mints €O tokens to the verified wallet address.



3.5.2 Bond reserve execution flow

Euro inflows collected from users are converted into high-grade EU sovereign bonds using a compliant bond laddering strategy. This method minimizes liquidity risk and ensures stable collateral value (MiCAR Articles 32–33).

- Fiat inflows are aggregated in a treasury account.
- An automated Execution engine selects appropriate bonds using a scoring model based on yield, maturity, and credit rating (β^t).
- Batches of trades are submitted to licensed venues such as Tradeweb or Euroclear.
- The custodian confirms settlement of bond purchases and updates records.
- The BondPriceOracle posts current market value of bond reserves on-chain.
- The ReserveVerifier calculates NAV and enforces minting/redemption ceilings.

3.5.3 Compliance & Risk mitigation

- Wallet-level KYC/AML enforcement under EU AMLD5 and Latvian regulator rules.
- Tamper-resistant issuance via oracle-verified proofs and reserve sufficiency checks.
- Anti-overissuance mechanisms embedded in ReserveVerifier logic.
- Interest rate and redemption risk mitigation via bond laddering and liquidity buffers.
- Role-based access control, multi-sig execution, and incident logging.

3.5.4 User onboarding & Minting framework

Stableo is designed to allow both retail and institutional users to mint and redeem €O tokens without Stableo itself operating as a regulated financial institution. This is achieved by outsourcing all fiat-related activity, custody, and KYC/AML compliance to trusted third parties (EMIs or licensed banking partners).

- Retail users (Non-custodial access)
  - At launch, retail users interact via Stableo's web interface (Phase 1), providing only a verified email address to initiate fiat transfers.
  - They are redirected to a partner EMI (e.g., Paysera, Lemonway) which handles:
    - KYC (e.g., ID upload, liveness check),
    - Fiat deposits (via SEPA Instant / TIPS),
    - Transfer confirmation.
    - Once fiat clears, the EMI triggers Stableo's treasury minting via API and the €O tokens are delivered to the user's wallet (e.g., MetaMask).
  - In Phase 2, this interface can be removed and replaced with fully automated API integration allowing compatible apps (wallets, fintechs, neobanks) to embed Stableo minting/redemption logic via SDKs.
  - Stableo never stores PII or processes identity data — all AML/KYC is done by the fiat on-ramp partner.
- Institutional users (Custodial or Treasury use)
  - Institutional clients (e.g., treasuries, remittance platforms, fintech APIs) initiate large mints/redemptions via direct API access or manual settlement interface.
  - These clients undergo KYC and onboarding with the banking partner, who handles fiat inflows and compliance.
  - Funds may be settled via TIPS, TARGET2, or SWIFT, depending on volume.
  - Stableo contracts perform token minting after treasury-side validation.

Stableo's approach to onboarding is structured around minimizing regulatory exposure while maximizing usability for both retail and institutional clients. The architecture deliberately decouples fiat interactions and KYC obligations from the protocol itself, delegating them to licensed intermediaries such as Electronic Money Institutions (EMIs) and regulated banking partners. This allows Stableo to maintain non-custodial, crypto-native architecture while remaining compliant under MiCAR and other EU financial frameworks.

No internal custody or KYC handling is currently planned inside Stableo. Stableo assumes a modular operational model. It never directly handles user identity information. Instead, fiat deposits, KYC/AML checks, and any required transaction screening (e.g., sanctions list compliance) are performed by third-party partners. This approach keeps the protocol outside the scope of direct financial licensing obligations. Users are segmented in 2 parts - retail users with lightweight onboarding via a web portal (Phase 1) with email verification, redirect to EMI for full KYC and deposit where the minted tokens go to a MetaMask (or similar) self-custody wallet. While other groups - institutional users require heavier onboarding with banking or custody partners. Funds wired via TIPS, TARGET2, or SWIFT. Minting controlled via direct API or settlement interfaces.

EMI partners must offer instant or same-day settlement via SEPA Instant or TIPS to ensure same-day redemption as required. Retail users may initially need guidance on wallet creation and transaction tracking. Stableo wants to phase out any email interface in favor of API-based flows and fintech integrations in Phase 2. Institutional clients are assumed to already have KYC profiles with the bank partner, minimizing friction. Similar to other major players:

- USDC (via Circle): Institutional onboarding requires KYB and fiat deposit via Silvergate, Signature, or similar banks. Retail access via fintechs.
- EURe (by Monerium): On-chain euro token issued via IBAN deposit after completing KYC with Monerium (an EMI).
- Jarvis Euro (jEUR): Minted through DeFi bridges or synthetic exposure, no direct KYC but limited fiat on-ramp.

Stableo blends these models by enabling direct mint/redemption with a licensed partner, while avoiding direct custody/KYC risks. All legal obligations tied to fiat handling stay with the EMI/bank. Stableo is abstracted as a protocol.The interface can be embedded into wallets, fintech apps, and neobanks via SDKs or hosted APIs and local rules and regulations applied on the integrating side, lifting extensive conformity requirements off Stableo. The minted tokens are tied to real-time treasury inflows with no internal user account system.

3.5.5 Summary of System architecture

- High capital efficiency through optimized bond purchasing.
- Full transparency via Merkle proofs, smart contract events, and public dashboards.
- MiCAR Article 20 & 33 compliance, including risk governance and user protection disclosures.
- Flexibility to adapt monetary parameters via governance under Latvian law.
- Real-time reporting tools compatible with Latvijas Banka's supervisory standards.

This layer provides the financial backbone of €O's stability promise, linking euros in the banking system to programmable collateral on-chain. It enables compliant, trust-minimized, and high-availability issuance of a euro-native digital asset.

3.6 Smart contract & Service integration layer

This layer enables programmable utility for €O in a wide range of institutional, treasury and DeFi contexts, such as:

- Corporate treasury management: large corporates can automate cross-border settlements, run payroll in €O or hedge receivables using programmable rulesets.
- Tokenized funds & Money markets: asset managers can use €O to launch euro-denominated liquidity pools, yield products, or tokenized funds with on-chain NAV[17].
- Compliant DeFi integration: protocols can whitelist €O for lending, collateralization, and derivatives with compliance modules such as on-chain identity verification or transaction tracing.
- Payment & FX Rails: PSPs[18] and FX providers can integrate €O for instant cross-border settlements at lower cost, with real-time transparency and no correspondent banking delays.

This layer ensures that €O is not just a store of value, but a composable *euro* liquidity primitive that is foundational to the EU's future financial infrastructure.

The flywheel operating mechanism.

Step 1: Initial investor funds create the foundation

The cycle starts with early investor capital, e.g., an initial €10M tranche. This capital is deployed into short-duration, highly liquid euro-denominated sovereign bonds, balancing yield capture with capital preservation and liquidity. These bonds form the NAV backing each €O token on a 1:1 basis delivering a fully reserved model that reassures regulators, exchanges, and end-users alike.

Step 2: Demand-driven AUM multiplication

Once minted, €O tokens enter circulation: trading on exchanges, being integrated into fintech wallets, or used in DeFi liquidity pools. As real-world demand rises, the protocol must mint additional €O, which in turn requires buying more eurobonds increasing AUM.

This growth is non-linear from the investor's perspective:

- Many costs (technology, audits, governance) are fixed or grow sub-linearly by utilizing economies of scale.

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[17] Net Asset Value. Total value of a fund's assets minus its total liabilities. This means that the true value of the tokenized fund is transparently and automatically determined and reflected on the blockchain, allowing for new levels of efficiency, trust and programmability in fund management.

[18] Payment Service Provider (PSP) is a third-party company that helps businesses accept electronic payments from their customers. They act as intermediaries between businesses (merchants), customers, and various financial institutions (like banks and card networks).

- Both yield (from new bonds) and fees (mint/burn and custody fees) scale proportionally with AUM. As AUM increases (e.g., from €10M to €100M+) the protocol benefits from operating leverage, where net profit per euro of AUM rises.

$$Net\ Operating\ Margin = \frac{Bond\ yield + Fee\ income - Variable\ costs}{AUM}$$ [19]

Step 3: Yield & fee income fuel the flywheel

The Stableo treasury earns two main income streams:

- Bond yield: predictable, risk-adjusted returns (e.g., 2–4% annualized) e.g., at €100M AUM, a 3% bond yield contributes ~€3M per year.
- Protocol fees: including mint/burn spreads (e.g., 0.1–0.3%), custody fees for large holders, and integration fees from partner platforms. Depending on lifecycle stage the fees might be waived to decrease new holder/user onboarding barriers and compete with other stablecoins. If mint/burn and custody fees add another ~€0.5M, total annual revenue becomes ~€3.5M. After costs, the treasury retains a substantial profit margin.

Step 4: Controlled reinvestment & investor distributions

A portion of net profits is distributed directly to early investors, analogous to dividends (depending on growth strategy). The remainder is reinvested into carefully selected, higher-yielding, euro-denominated opportunities under governance control (low-risk structured notes, AI-driven short-term strategies to capture micro-yield dislocations).

This dual-track structure mirrors a core–satellite strategy:

- The "core" preserves capital and backs €O's 1:1 peg.
- The "satellite" targets higher alpha from net profits, not from the €O reserves.
- Over time, this reinvestment compounds, further growing AUM and profit.

Step 5: Compounding effect & asymmetric returns

Over multiple cycles, the model produces asymmetric investor returns:

- Initial yield on risk-free bonds
- Growing share of fee-driven income (which scales with AUM)
- Exposure to reinvestment alpha without directly risking reserve capital

Illustratively, if AUM grows from €10M to €100M over 2 years, and the reinvestment pool compounds at even modest returns (e.g., 5–7%), early investors' effective IRR can substantially

[19] Variable costs - stablecoins are blockchain-based digital currencies pegged to bonds expressed in euro. When stablecoins are used for transactions or holding user funds, issuer operates within a crypto infrastructure - this introduces new cost drivers, particularly variable ones, because many of these costs are:

- transaction-dependent (e.g. gas fees, bridge costs)
- volume-based (e.g. custodial fees per euro held)
- market volatility-sensitive (e.g. slippage, spread during rebalancing)

exceed the original sovereign bond yield while remaining in a capital-light, regulated structure. Traditional eurobond investing offers safety but limited upside. By contrast, Stableo's model unlocks three value layers:

- Base layer: predictable sovereign bond yield.
- Scaling layer: demand-driven AUM growth, generating fee income and operational leverage.
- Alpha layer: controlled reinvestment of profits into higher-yield opportunities.

This creates a self-reinforcing flywheel: rising demand increases AUM → higher profit → larger reinvestment pool → more income → further investor distributions. In result Stableo delivers a uniquely balanced investment profile that combines downside protection (fully reserved eurobonds) with asymmetric upside (profit reinvestment and fee growth).

3.7 Stability, utility and expansion

Stableo's design prioritizes:

- Stability: full collateralization, clear regulatory license and real-time attestations.
- Utility: API-first design, smart contract compatibility and institutional UX.
- Scalability: cross-chain operability, euro-native use cases, and integrations with DLT-native securities and funds.

Future versions will include:

- Permissioned versions of €O for banks and fund managers.
- Real-world asset (RWA) wrappers with embedded €O flows.
- SDKs and plug-ins for integrating Stableo into investment management, ERP, and payment software.

Stableo is designed as a multi-layered financial and technological system in which each layer plays a distinct but interdependent role. These layers (Regulatory & Reserve, Tokenization & Issuance, and Smart contract & Service integration) combine to form a robust, scalable, and secure infrastructure that enables euro-backed digital assets to function at institutional-grade standards. To illustrate how these components work together, we describe the flow of a typical lifecycle of a €O stablecoin, from minting to usage to redemption, and how each layer reinforces trust, security, and utility.

In Stableo's design, three complementary layers (tokenization & issuance, reserve policy & bond laddering and smart contract utility) work together to transform demand for a fully reserved stablecoin into scalable, asymmetric investor returns.

- At the base layer, the tokenization & issuance system ensures that each €O is minted or burned only against verified, ECB-eligible reserves, using strict compliance controls, KYC/KYB, AML risk scoring, and on-chain proof-of-reserves. This layer builds user trust, regulatory alignment, and real-time auditability making €O credible to fintechs, exchanges, and institutional treasuries.

- The second layer, the reserve management and bond ladder policy, focuses on capital preservation and predictable yield. By investing in short-duration, highly liquid euro-denominated sovereign bonds, the protocol captures a stable base yield (e.g., 2–4%) while reducing duration risk. A carefully structured tranche system ensures liquidity for redemptions without forced selling, even during market stress. This design underpins the peg and enables scale.
- The Investor Flywheel turns this solid foundation into compounding growth. Rising €O demand increases AUM, boosting bond yield and fee revenue. Controlled reinvestment of profits into higher-yield opportunities adds an alpha layer without endangering reserve capital. For investors, this means downside protection (fully backed reserves), operational leverage from growing demand, and reinvested alpha: a combination rarely offered by pure stablecoins or passive bond funds.

Together, these layers do more than secure the €O peg: they create a capital-efficient, regulated and scalable profit engine. By explaining to investors not only how the system is built but why each design choice directly supports asymmetric, compounding returns, Stableo's whitepaper turns a technical architecture into a powerful, investor-friendly growth story.

4. Economic model

The global stablecoin market has expanded dramatically in recent years, growing from under $10 billion in 2019 to over $150 billion by mid-2025, according to The Block Research and CoinGecko data. The market is overwhelmingly dominated by USD-pegged stablecoins, which represent more than 90% of supply, driven by high liquidity in decentralized finance (DeFi), crypto trading pairs, and dollar dominance in international trade. In contrast, euro-denominated stablecoins remain underdeveloped, making up only about 2–3% of global stablecoin supply (~€3–5 billion). Several factors like fragmented European banking infrastructure and inconsistent regulatory oversight have limited *euro* stablecoin growth to date. The lack of large-scale DeFi demand denominated in EUR together with low or even negative *euro* interest rates over the past decade have reduced incentives for holding *euro* reserves or *euro* alternatives, not driving the market. However, the implementation of MiCAR in 2024–2025 fundamentally changes the regulatory environment. For the first time, it establishes unified rules for asset-referenced tokens (ARTs), clarifying capital, governance and disclosure requirements. This regulatory clarity is expected to unlock substantial new demand from regulated financial institutions, neobanks, corporates and payment providers looking to integrate compliant *euro* stablecoins into their offerings.

The EU bond market outlook is shaped by major macroeconomic and geopolitical factors. According to the Draghi report and recent EU policy discussions, the EU plans significant fiscal expansion: €100-120 billion annually for military and defense modernisation in response to geopolitical threats, alongside digital infrastructure investment. Financing these objectives will likely require sustained high-volume issuance of AAA/AA-rated euro-denominated bonds, expanding the high-quality liquid asset (HQLA) pool available to stablecoins like €O. ECB data (June 2025) shows EU sovereign gross issuance is already up ~18% YoY. Meanwhile, Draghi's vision emphasizes stronger capital market integration and digital asset harmonization, signaling supportive structural policy for tokenized euro-denominated bonds.

Simultaneously, the digital asset market is maturing. MiCAR-compliant products have seen rising institutional inflows: over €14B of new stablecoin and tokenized bond assets were created in the last 12 months, per ESMA. DeFi in the EU is likely to grow by 15-20% annually as regulated offerings replace offshore alternatives, attracting institutional liquidity and enhancing the on-chain *euro* ecosystem. Increased demand from non-EU investors, such as Blackstone (largest private equity firm in the world), BlackRock (largest asset manager in the world) etc. (seeking diversification amid U.S. fiscal challenges (with U.S. debt-to-GDP surpassing 130% and real yields remaining volatile)) could shift capital into euro-denominated assets. Tokenized assets act as a direct, digital gateway - investors can bypass intermediaries, lowering cost and time-to-market, thus improving demand elasticity.

Beyond institutional adoption, DeFi protocols abroad can integrate *euro* stablecoins as collateral or liquidity pairs, driving indirect demand for underlying EU bonds. This arbitrage effect (non-EU DeFi users needing regulated, liquid EUR exposure) creates an additional demand vector. This combination of geopolitical risk hedging, regulatory clarity and digital infrastructure makes EU-denominated stablecoins not just a passive mirror of reserves but a proactive engine channeling global liquidity into European capital markets.

The economic model presented herein reflects the Issuer's commitment to full asset-backing, prudent reserve structuring and alignment with the stability criteria outlined in MiCAR, specifically those applicable to ARTs. In accordance with the supervisory expectations of Latvijas Banka, the model incorporates quantitative stress testing, conservative reserve management practices and operational safeguards to ensure that token redemptions remain fully matched by HQLA, even under adverse market conditions.

4.1 Buffer modeling & stress analysis

Over the past 30 years AAA/AA euro-denominated sovereign bonds have shown maximum drawdowns between 2.5%–3.2% during crises: 2008, 2011 European debt crisis, COVID-19 shock, and 2022–23 rate volatility. Factoring in geopolitical events (Ukraine war, Middle East conflict), we observe occasional spreads widening, but no foundational loss of principal. We use this empirical volatility range as the basis for our buffer design.

For buffer size and calculation we adopt a liquidity buffer calculated as:

$$Buffer = Max\ drawdown_{30y} + Regulatory\ safety\ margin$$ [20]

Using a conservative upper bound: 3.2% + 0.8% margin = 4% buffer. This buffer is held in cash or ECB-eligible instruments, ensuring full redemption capability even if bond prices drop. Stableo will conduct quarterly reviews and run reverse stress tests to simulate 14-day inflow/outflow shocks, ensuring buffer adequacy under a 1-in-100 year scenario. Findings show that a 4% buffer comfortably covers peak redemptions without triggering fire sales.

4.2 Reserve operations

All EUR inflows (mint-triggering fiat) are converted into euro-denominated sovereign bonds within 7 days using our bond laddering approach (with exception if sufficient cash buffer levels are required to maintain). This process ensures minimal idle capital, consistent yield capture and liquidity preservation. Coupon income is first allocated to operational costs; residual flows to buffer replenishment, keeping buffer at ≥4%.

[20] Regulatory safety margin - is a risk-based capital add-on above expected losses (drawdowns), often aligned with banking-style Value-at-Risk (VaR) or Liquidity Coverage Ratio (LCR) logic. This margin covers: 1) Tail risk exposure (e.g. >99% confidence loss events), 2) redemption volatility risk and 3) liquidity mismatch between assets and liabilities. In other words, the regulatory safety margin is an additional reserve component (1-2.5%) calibrated to stress conditions, redemption volatility, and operational risk, aligned with MiCA Article 36's prudential standards and reflecting financial stability principles from MMF and e-money regulations.

Reserve allocations:

- 95–97% in *euro* sovereign bonds (ECB repo-eligible, AAA/AA, EUR-denominated)
- 3–5% in a cash buffer with EMIs

Funds are held segregated, audited, and reported via on-chain oracles, enabling compliance with both MiCAR and Latvian supervisory standards with daily transparency.

4.3 Market conditions & Sentiment

The *euro* stablecoin landscape grew ~30–44% in H1 2025, with total supply nearing USD 500M[21], driven by MiCAR clarity and euro strength. EU stablecoin usage has risen from 16% to 34% of global volume[22]. This marks a shift from crypto experimentation toward regulated, euro-backed infrastructure. Simultaneously, Circle's IPO and move toward full-reserve banking underpin US stablecoins' model, reinforcing global trust and institutional interest[23]. Meanwhile, BIS has warned of stability risks from unregulated coins[24] emphasizing the need for currency-aligned, fully-backed euro options. These factors create a supportive environment for Stableo's model, which emphasizes full reserve backing, buffer robustness, MiCAR compliance and macro-aligned *euro* exposure.

To quantify market potential, €O adoption can be modeled in three scenarios (conservative, base case and aggressive) over a 5-year horizon (2025–2030), based on external references and internal economic assumptions:

- Based on ECB and SWIFT data, eurozone cross-border B2B payments exceed €12 trillion annually.
- Stablecoins typically sustain ~0.1–0.3% of annual transaction volume as float or liquidity buffer (historical ratio from USDC, USDT).
- Even conservative penetration of *euro* flows implies an addressable stablecoin supply of €12–36 billion, before considering additional retail, DeFi or treasury demand.
- Additional demand comes from neobanks (€2–4 billion), euro-denominated DeFi pools (€1–3 billion), and corporate treasuries seeking programmable liquidity.

Over time, market saturation may be driven by:

- Regulatory convergence (e.g., new EBA guidelines, MiCAR revisions).
- Competitive entrants (other MiCAR-compliant euro stablecoins).
- Broader adoption of CBDC.

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Scenario	5-year CAGR	Estimated *euro* stablecoin supply (2030)	Time horizon assumption	Key drivers
Conservative	~20%	~€10–15 billion	Gradual growth over 5–6 years	Limited DeFi uptake, moderate neobank adoption, cautious institutional adoption
Base case	~35%	~€20–30 billion	Acceleration starting 2025–2027, then stabilizes	Regulatory clarity, growing cross-border payments, DeFi integration, corporate treasuries demand
Aggressive	>50%	€40–50+ billion	Sustained high growth over full 5–6 years	Deep DeFi integration, widespread fintech adoption, pan-EU digital asset rails, cross-chain liquidity

Potential Central Bank Digital Currency[25] (CBDC) together with MiCAR estimates to bring significant boost in European digital markets and increase trust in digital assets. The ECB's ongoing digital euro project is a retail-focused CBDC aimed at micropayments and wallet balances up to €3,000–€4,000 per user.

Key points based on ECB communications (pilot):

- Primarily for person-to-person, consumer-to-business payments.
- No yield on digital *euro* balances (non-interest bearing).
- Focus on privacy, offline payments and EU-only transactions.
- From an economic perspective, the digital *euro*:
    - complements rather than replaces private ARTs like €O, which target programmable finance, cross-border B2B flows and DeFi integration.
    - will not address demand from institutional treasuries, DeFi liquidity pools, or programmable settlement systems.
    - likely absorbs part of small-value retail stablecoin demand, but leaves larger, more complex programmable use cases to private issuers.

Key differentiation from Stableo includes flexible operational yield (from bond coupons), subject to MiCAR caps to Stableo investors. €O can directly integrate into DeFi and tokenized asset systems and serve B2B and multi-chain payments, including outside EU-only environments. In a competitive market, €O's long-term economic value relies on structural differentiation beyond branding:

[25] https://www.edps.europa.eu/press-publications/publications/techsonar/central-bank-digital-currency_en

- Robust reserve design and transparency.
- €O reserves are 100% covered by ECB-eligible euro-denominated sovereign bonds (AAA/AA-rated) and a liquidity buffer based on historical stress test scenarios.
- Reserves are segregated, subject to external audits and daily on-chain attestations, aligning with MiCAR's strictest ART requirements.
- Buffer is quantitatively modeled (see section 4.1) to withstand worst-case bond drawdowns (~3–4%).
- Liquidity-optimized buffer and operational design:
    - Fresh inflows converted weekly/bi-weekly to reduce bond spread cost.
    - Coupon payments used first to cover operational expenses and then to top up the liquidity buffer.
    - Rule-based allocation: ~95-97% in bonds, ~3-5% in liquid cash or EMI deposits.
- Programmable architecture and DeFi integration:
    - Smart contract layer supports whitelisted DeFi protocols and cross-chain bridges.
    - Enables euro-denominated lending, trade finance, and collateralized stablecoin markets.
    - A neutral, private-sector issuance model allows €O to integrate into diverse financial systems without central bank control.
- Scalability and multi-tenant design:
    - API-first approach supports integration by neobanks, fintechs and payment providers.
    - Direct institutional access for large B2B treasury operations.

These elements together create a structurally differentiated product aligned to MiCAR while supporting practical, real-world use cases with economic rationale that is built on reduced FX risk for eurozone businesses operating cross-border inside the EU. The instant settlement and programmable financial operations (e.g., auto-payments, escrow) allow €O to be used with full functionality and fully integrated in everyday operations maintaining collateral for tokenized assets and euro-denominated lending pools. The historical data (e.g., SWIFT and ECB Payment Statistics) supports stablecoin floats at ~0.1-0.3% of annual transactional volumes meaning that for EU cross-border payments of ~€12-15 trillion/year, even conservative adoption supports multi-billion-euro demand.

4.4 Impact of falling interest rates on revenue sustainability

Important considerations are changes in interest rates. Rising interest rates improve bond yields, enhancing sustainability. This poses a risk that during declining interest rates as new capital comes in, it can only be invested in newly issued bonds at the lower yield and the coupon payments (which fund operational expenses, buffer, and potentially a yield to token holders if allowed under MiCAR) shrink over time. At the same time the bonds that are already held with higher coupons, go up in the market. However, since €O is fully redeemable at par, these unrealized gains cannot be distributed. Meaning that the operational cash flow from coupons is lower, even if the NAV per bond is higher (lower bond coupons equals less income to cover, tokenization of real-world assets (RWA) increases demand for euro stable collateral). If rates fall very far (e.g., back to ~0% or negative, as seen in the EU in the past decade), the income from bonds could become too small to cover costs.

In 2014–2021, the ECB deposit rate was negative (down to -0.5%). Stablecoins based on euro bonds would have struggled to sustain operational costs. Current ECB rates are positive, but the cycle can reverse. This volatility highlights why a dynamic reserve & buffer strategy is essential for any euro stablecoin aiming for long-term sustainability. As the Stableo's reserve model relies primarily on highly rated EU sovereign bonds and cash equivalents, the economic environment (specifically interest rate cycles) directly affects operational sustainability. When interest rates are high, new inflows can be invested at higher yields, generating sufficient coupon income to cover operating expenses (compliance, audits, IT, custodial costs), reinvest into the liquidity buffer and possibly to support moderate strategic initiatives (e.g., integration, infrastructure).

Scenario	**Average portfolio yield**	**Annual gross coupon income (on €100M)**	**Estimated operating costs**	**Buffer allocation**	**Net surplus/deficit**
High-rate (4%)	4.0%	€4.0M	€1.5M	€1.0M	+€1.5M surplus (can strengthen buffer / reinvest)
Moderate-rate (2%)	2.0%	€2.0M	€1.5M	€0.4M	+€0.1M slight surplus
Low-rate (0.5%)	0.5%	€0.5M	€1.5M	€0	-€1.0M deficit (requires other income / reserve usage)

Assumptions:

- €100 million fully collateralized reserve (95% bonds, 5% cash)
- Conservative annual operating costs (licensing, legal, IT, audits, personnel)
- Buffer allocation goal: at least 0.4–1% per year during positive yield periods

Mitigation of this issue would include:

- Diversification of part of the reserves into longer-term bonds (duration risk managed) to lock in higher coupons (see laddering strategy section).
- Lowering fixed costs (short term operational strategies, long-term investments).
- Safety buffer during high-rate periods (periods of high yield to overfund the liquidity buffer, building reserves)
- Focus on adoption for use cases that generate transaction fees (DeFi, payment APIs) decoupling business income from purely bond yield. Low mint/redeem fees or on-chain

transaction fees generate steady revenue decoupled from bond yields. Fee models can be adjusted dynamically depending on rate environment.

- Separate legal entity (sister company) that:
  - Can invest in higher-yield, riskier assets (corporate bonds, real estate-backed notes, or carefully chosen DeFi strategies).
  - Entity outside the fully collateralized reserve to remain MiCAR-compliant.
  - Its profit can be used to buy and hold €O tokens on the secondary market, increasing demand and stabilizing the token's market cap.

This effectively adds an informal secondary buffer of demand which creates buy pressure in times of market stress and keeps the operational reserve model itself purely conservative and MiCAR-compliant. The sister company is a close strategic partnership that is part of the general strategic partnership approach: Integration into payment networks, PSPs, and DeFi protocols to create volume and transaction-based revenue. For additional income streams a tiered product approach should be divided offering optional value-added services (e.g., API-based payments, automated compliance tools) for B2B users. Over time other MiCAR-compliant ARTs (CHF, SEK, DKK) support can be launched to diversify reserve income sources.

By dynamically adjusting reserve strategies, adding fee-based revenue, and leveraging synergy with the sister firm, the €O stablecoin can remain sustainable across the full interest rate cycle.

4.5 Economic safeguards & governance

The €O stablecoin architecture leverages a quantitative liquidity projection model to anticipate redemption pressure under various market conditions. At its core, the rolling liquidity forecast enables near real-time monitoring of net inflows and outflows across issuance, coupon receipts, redemptions, and operational expenses.

$$\Delta L_t = \sum_{i=1}^{N_t} (I_{i,t} - O_{i,t})$$

Calculating the net change in liquidity (ΔL) over a time period t by summing up all inflows and outflows, where:

- ΔL_t = Change in liquidity during time t. Positive means extra liquidity, negative means potential shortfall.
- N_t = Number of transactions or liquidity events during time t.
- $I_{i,t}$ = Inflow amount from transaction i during time t. Could include new coin purchases, coupon income, bond maturities.
- $O_{i,t}$ = Outflow amount from transaction i during time t. Could include redemptions, operating expenses, reinvestments.

By integrating high-frequency settlement data and forecasted market activity, this model predicts liquidity shortfalls before they materialize, preventing forced asset sales under unfavorable conditions. The system dynamically evaluates whether projected liquidity exceeds the immediate buffer (B_c) and maturing bond tranches ($\Sigma_{j=1}^{M_t} M_{j,t}$), ensuring that redemption coverage remains intact without impairing long-term yield strategy.

Beyond purely reactive measures, this framework functions as a forward-looking liquidity radar, automating reserve rebalancing decisions in advance of stress events. For instance, if the forecast identifies a €5M redemption cluster coinciding with a period of low bond liquidity, the system can sell liquid tranches early, reducing NAV volatility and transaction slippage. Such an approach replaces manual treasury risk decisions with algorithmic execution governed by transparent rules, improving operational scalability and investor confidence. Additionally, daily automated reconciliation between on-chain reserve data and off-chain custody statements ensures the model uses real, verified figures rather than forecasts alone, enhancing robustness.

Quantitative governance & Strategy adjustment

The governance layer is explicitly designed to be adaptive and data-driven rather than static, ensuring long-term resilience in volatile markets. The buffer ratio (b) is recalculated periodically using the equation:

$$b = b_o + k \cdot \sigma \cdot \sqrt{V_f}$$

Where:

- b_o = the regulatory minimum (e.g., 3%)
- σ = historical asset volatility
- V_f = forecasted redemption volume
- k = is a risk-adjustment coefficient set by the governance committee.

This mechanism ensures that buffer size scales dynamically: rising market volatility or increased redemption risk will automatically expand liquidity buffers, while stable conditions optimize capital efficiency by lowering idle cash. When market volatility (σ) rises or large redemptions (V_f) are forecast, buffer increases automatically that keeps peg stable without manual emergency measures.

Bond selection strategy, expressed by the weight vector (β_t), is equally dynamic. Governance recalibrates it quarterly by balancing duration, yield-to-maturity, liquidity score, and correlation with macro risk factors (e.g., geopolitical tension indices, ECB rate forecasts). For instance, during periods of inverted yield curves or sudden geopolitical risk, the model may overweight shorter-duration bonds or shift toward higher liquidity tranches. The reinvestment horizon (h) is also shortened when market volatility exceeds a threshold (θ), improving reaction speed to external shocks. Together, these adaptive strategies allow the stablecoin to evolve in response to market data, preserving full collateralization and stability without relying on manual interventions alone.

Bond selection weights (β_t) are calculated from the bond selection model and combine duration, yield, liquidity score, correlation to macro risk factors. Typically recalibrated quarterly (or even monthly in volatile times).

$$\beta_t = argmax\left\{Score\ = \omega_1 \cdot YTM + \omega_2 \cdot Liquidity\ + \omega_3 \cdot Duration\ Risk\ + \omega_4 \cdot Correlation\ With\ Macro\ Risk\ Factors\right\}$$

Where:

- YTM = yield-to-maturity
- Liquidity = internal liquidity score (e.g., days to sell without >0.1% slippage)
- Duration Risk = exposure to rate changes
- Correlation with macro risk factors = e.g., correlation with ECB policy rate changes, geopolitical indices
- ω_1, ω_2, ω_3, ω_4 = governance-tuned coefficients.

θ defines volatility threshold (e.g., if 30-day annualized volatility of euro-denominated bond index > θ). Once triggered h shortens from 24 to 12 to 6 months.

Each parameter is defined and explained within the risk management framework and is built in the governance dashboard. Depending on the nature of change the thresholds can change automatically or by following the internal agreement procedure.

4.6 Additional economic considerations & Systemic resilience

The €O stablecoin economic framework acknowledges that large asset-referenced token (ART) issuers can unintentionally amplify systemic risk during crises if forced to liquidate large positions in illiquid markets. To mitigate this, our tranche ladder design ensures ~20–25% of the bond portfolio naturally matures each quarter, aligning passive cash inflows with predictable redemption needs. This passive mechanism reduces reliance on active market sales during stressed periods, smoothing out liquidity events and avoiding procyclical effects that could worsen bond sell-offs. As a result, the stablecoin becomes a shock absorber rather than a systemic amplifier.

Predictable rebalancing also benefits the broader euro-denominated asset market by maintaining stable demand for government bonds, even when other market participants withdraw. The model leverages historical data from the 2011 sovereign debt crisis and 2022–23 rate hikes to design bond maturity ladders and reserve thresholds that withstand significant shocks. By embedding liquidity at multiple layers (cash buffer, maturing bonds, and real-time monitoring) the stablecoin's operational profile aligns with MiCAR's goal of financial system stability rather than speculative volatility.

The Markets in Crypto-Assets regulatory framework and the supervisory expectations of Bank's of Latvia mandate not only full asset-backing but also structured liquidity stress testing. The Stableo's model goes beyond compliance by integrating weekly scenario-based forecasts that simulate redemption spikes of ±30%, yield shifts of ±200 basis points, and EUR/USD FX shocks of ±15%. Governance committees analyze these scenarios quarterly, updating key parameters like buffer ratio b, bond selection vector β_t, and reinvestment horizon h based on real market data.

Beyond regulatory compliance, these measures enhance transparency: all stress test procedures, model logic, and results are documented and auditable, aligning with ECB best practices for financial institutions. Additionally, data from on-chain reserve monitoring is reconciled with off-chain custodial statements, providing an immutable and transparent reserve status. By codifying these safeguards, the stablecoin not only meets but exceeds MiCAR's expectations, making it a benchmark for responsible digital asset issuance in the eurozone.

In designing this euro-pegged stablecoin, our economic model aims to balance transparency, resilience, and scalability within a regulated EU framework. At its core lies a dynamic buffer strategy built on historical stress events and rolling liquidity monitoring. By targeting an operational buffer of 3–4% beyond the mandatory 100% reserve coverage, the model directly addresses observed worst-case bond drawdowns while maintaining operational flexibility. This approach is not static: it uses real-time bond yield data, macro volatility indices, and redemption patterns to recalibrate buffer size and composition each quarter, ensuring the system can withstand both foreseeable and unexpected liquidity shocks.

Stableo's reinvestment strategy systematically transforms coupon income into additional liquidity or reinvests it based on quantitative triggers. Adaptive bond selection (driven by a vector of weights (β_t) reflecting duration, liquidity score, and macro correlation) ensures the reserve portfolio remains responsive to changing market regimes. This methodical yet adaptive structure reduces reliance on human judgment alone, creating an inherently more robust and transparent reserve management system that aligns with the expectations of MiCAR and Latvia's central bank.

Recognizing the reality of market-driven stress, the model also includes a sister company buy-pressure mechanism. This complementary strategy allows a legally distinct entity to purchase the stablecoin during heightened redemption periods, adding external demand-side liquidity without diluting the stablecoin's 100% reserve principle. Governed by quarterly recalculated caps based on observed volatility and issuance patterns, this approach transforms external profits into internal resilience. It directly supports secondary market stability, making the stablecoin more attractive to institutional and cross-border investors who value predictable liquidity.

Looking ahead, macroeconomic forces present both risks and opportunities. The Draghi report forecasts sustained EU bond issuance driven by defense, green transition, and digital infrastructure investments. As EU member states tap capital markets more aggressively, the volume and diversity of euro-denominated bonds should rise, broadening the eligible collateral pool. Simultaneously, the likely introduction of the digital *euro* and MiCAR regulated stablecoins will reshape competitive dynamics. However, the model anticipates that demand from non-EU investors seeking diversification away from USD debt (and the relative safety of euro assets) will remain strong, providing an important growth channel even if domestic demand plateaus.

Altogether, this layered economic design (dynamic liquidity buffers, rule-based bond reinvestment, external buy-pressure, and regulatory alignment) provides a stable foundation for sustainable growth. It positions the stablecoin to thrive even in falling interest rate environments by leveraging diversified reserve composition, and to scale alongside growing euro-denominated digital asset markets. This chapter demonstrates that economic resilience is not achieved through size alone but through transparency, adaptability, and the careful integration of both defensive and proactive measures.

5. Technical architecture

This section outlines the technical architecture of Stableo across its product lifecycle, from the initial proof of concept (POC) through the minimum viable product (MVP) to the fully featured production system. The architecture is designed to achieve compliance with MiCAR regulations, operational resilience, security, and transparency, while remaining agile enough to iterate quickly as the market and regulatory landscape evolve.

Stableo's design philosophy prioritizes:

- Simplicity at the start – to reduce development complexity and validate core functionality.
- Security and compliance – in both on-chain and off-chain components.
- Modular extensibility – enabling phased addition of advanced features (e.g., automated compliance, self-custody options, integrations with external DeFi protocols).

Stableo will be built around a hybrid architecture that bridges secure off-chain processes with on-chain transparency and auditability. The solution leverages mature blockchain ecosystems, regulated fiat infrastructure, and modern cloud technologies to deliver a robust euro-pegged stablecoin product. The technical infrastructure supporting the Stableo token will be built to ensure secure, auditable, and MiCAR-compliant issuance and redemption mechanisms. All smart contract logic, reserve tracking, and access control systems have been designed to meet the standards of operational resilience, auditability, and segregation of client assets, as expected by Latvijas Banka and other competent authorities within the European System of Financial Supervision. This section describes the architecture and external integrations supporting supervisory oversight and real-time collateral assurance.

5.1 Architecture overview

The Stableo technical architecture is designed to deliver a euro-pegged stablecoin that is simple to use, secure by design, and scalable for mass adoption across the European market.

Stableo's core vision is to provide an institutional-grade infrastructure that combines on-chain transparency with regulated off-chain collateralization, aligned with MiCAR and European AML/CFT requirements.
The architecture is structured to iterate in phases: starting with a minimal, reliable proof of concept (POC); maturing into an MVP that adds automation and integrations; and finally evolving into a fully featured production system capable of supporting millions of users, partner APIs, and advanced financial operations.

Guiding principles include:

- Regulatory alignment first: design choices must anticipate MiCAR, PSD2/PSP/EMI frameworks, and ESFS reporting standards.
- Security by design: multi-layered approach covering smart contracts, off-chain infrastructure, and operational processes.

- Phased complexity: the early system is kept to minimal (to validate the market and control risk) while planning the architecture to support complex future features like dynamic coupon optimization or AI-based liquidity monitoring.
- Transparency & auditability: real-time publishing of reserves, open API endpoints for regulators, and on-chain proofs of collateral.

5.1.1 POC, MVP and production roadmap

The system will evolve in three deliberate phases, each with clear goals and scope. Phase 1 will be the Proof of Concept (POC) to validate minting & redemption flow, show real euro reserve tie-in. With a simple frontend and a lightweight backend service layer to connect the frontend, manage mint requests, and talk to external EMI API. Basic EVM-compatible ERC-20 contract with mint(), burn(), and a hard cap set manually. External EMI will be used for on/off ramp, manual back-office verification of mint eligibility, daily publishing of reserves, and manual fiat redemptions triggered by burn requests observed on-chain. to detect off-chain deposits and validate user identity (via EMI KYC). Minting is performed by a backend-controlled hot wallet only after deposit is confirmed.

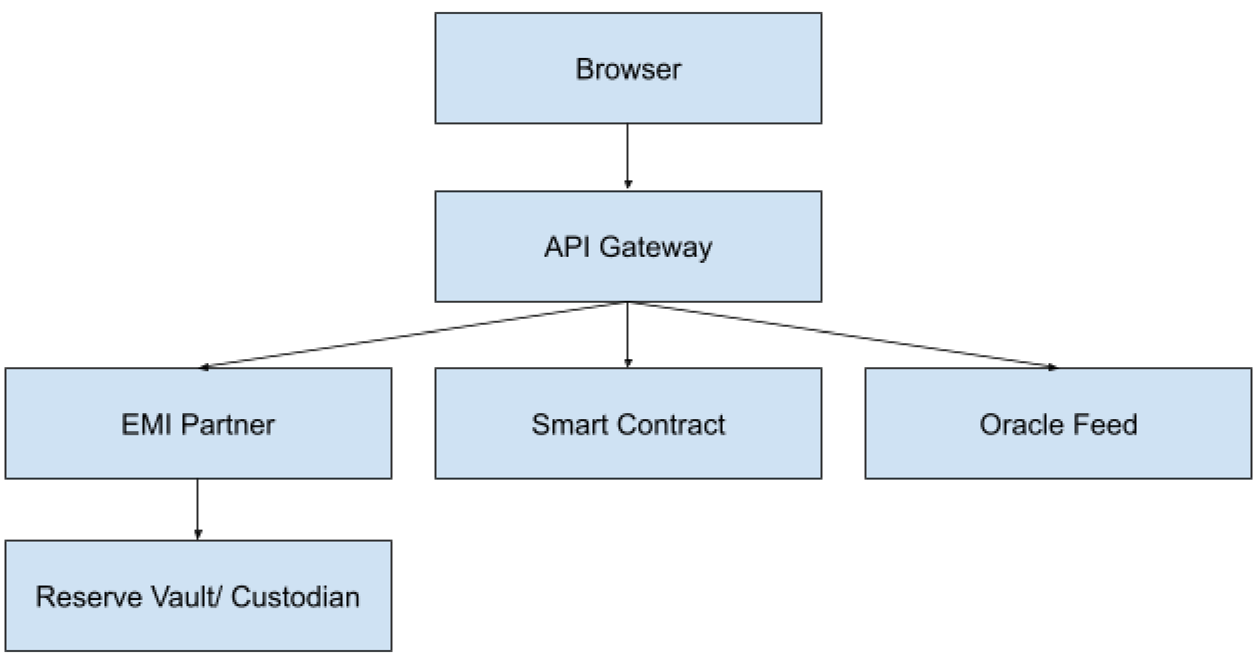
Minimum Viable Product (MVP) would be a market-ready solution concentrating on user flow automation, improved security and integration with real-time oracles and better KYC. Solution would contain full backend service, introducing queues (e.g. Celery) for background tasks and integration with external KYC providers (e.g., Onfido) as well as smart contracts and oracles. MVP will aim for automated reconciliation - minting only after successful EMI deposit confirmation.

Full production system on initial phase to provide basic products and enable scaling up for mass adoption, advanced financial logic and real-time reporting. Modular smart contracts with coupon ladder optimization, automatic buy/sell triggers for bond ladders, built-in governance voting and full AML compliance & transaction monitoring dashboard. One of the main pillars is delivery of external APIs for partners, exchanges and wallets. The solution is structured in a way to provide most value to main user groups with existing complexity and lean delivery approach that delivers basic functionality based on feedback and results.

Technical solutions and optimization:

- Smart contracts:
  - Early: single ERC-20 with mint/burn restricted to backend controller wallet. Burning starts as one-step but becomes two-step (*requestBurn()* + *finalizeBurn()*) to match off-chain fiat flow. Cap updated manually.
  - MVP: add setCap() controlled by governance & oracle.
  - Production: modular architecture (e.g., OpenZeppelin proxies) to allow adding features like dynamic fees or governance voting.
- Backend & API:
  - POC: endpoints for mint request (triggered after deposit), burn request (logs and watches chain). Backend polls EMI API to confirm deposit and then calls mint from the backend wallet.

    - MVP: internal task queues to manage delays (e.g., EMI API calls).
    - Production: separate services for user data, reserve management, audit logs to improve maintainability and scalability.
- Data storage:
    - POC: managed database.
    - MVP: introduce read replicas for scaling.
    - Production: separate analytics DB (data warehouse) for reports.
- Optimization:
    - POC: simple bond price feed.
    - MVP: oracles with real-time pricing
    - Production: integrate ladder optimization algorithms.
- Security:
    - POC: basic contract audit, backend wallet access restricted by IP/firewall + logs; manual approval process for mint/burn to reduce operational risk.
    - MVP: multisig treasury
    - Production: formal verification and multiple audit rounds.



By starting lean (POC), adding automation in MVP, and finishing with scalable architecture, Stableo maximizes speed to market and future resilience. Smart contracts evolve from simple capped ERC-20 to modular upgradeable contracts with built-in governance and reserve logic.

5.2 Blockchain layer

5.2.1 Selection of Blockchain platform

The choice of blockchain platform underpins the entire stablecoin ecosystem and has long-term implications for cost-efficiency, compliance alignment, ecosystem adoption, and future interoperability with financial services. For Stableo, the guiding requirement is a secure, EVM-compatible, low-fee environment that supports scalable issuance, redemption, and integration with regulated fiat systems in Europe.

Initial evaluations included Ethereum Mainnet, Polygon, Base, Optimism, and Gnosis Chain, prioritizing:

- EVM compatibility, which allows reusing established toolchains (OpenZeppelin, Hardhat, Foundry, The Graph) and reduces developer friction;
- Cost and speed, especially for high-frequency operations such as minting, burning, and on-chain auditability;
- Institutional adoption, with growing support for regulated stablecoins and tools supporting KYC, AML, and transparency reporting;
- Regulatory acceptability, with validator decentralization and Europe-aligned ecosystem maturity;
- On-chain analytics integration, to support regulatory dashboards, internal monitoring, and public transparency.

Polygon PoS was selected as the MVP launch chain due to its balance between performance and maturity. It offers sub-cent transaction costs, high finality, and integration with existing stablecoins (EUROe, USDC) and major custodians. It is broadly accepted among compliance-oriented DeFi projects and aligns well with projected MiCAR regulatory interpretations. The POC phase will be deployed on a testnet (Polygon Mumbai or Ethereum Sepolia), simulating the mint/redeem process with test euros and validating the off-chain to on-chain bridge architecture. The long-term plan leaves room for migration to rollups or L2s (e.g., Base, Optimism, or zkSync) once market demand, scalability needs, or cost-efficiency makes it favorable. Non-EVM chains (Solana, Avalanche, etc.) were excluded in early phases due to higher integration overhead with backend and EMI APIs, and limited interoperability with Ethereum-native ecosystem tools required for fiat proof, analytics, or oracles.

5.2.2 Smart contract design

Stableo's smart contract suite is purpose-built for a fiat-backed stablecoin with off-chain collateral validation. It is based on a minimally extended ERC-20 implementation that introduces tight mint/burn controls, a dynamic supply cap, and separation of operational vs. governance-level access.

Minting and Redemption with EMI integration - the core model assumes fiat operations are handled via a regulated Electronic Money Institution (EMI) that processes *euro* deposits, performs KYC, and executes redemptions. Minting and burning of Stableo tokens reflect these off-chain fiat movements in a secure and traceable manner.

- Minting flow:
  - Users send euros to an EMI-held IBAN (with structured reference).
  - The backend monitors the EMI API for cleared deposits.
  - Once verified, the backend-controlled hot wallet mints the equivalent amount on-chain to the user's address.

In the MVP, only the backend has permission to mint. In production, this role may shift to a licensed mint controller with regulated access.

- Burning flow:
  - A user initiates a burn request via the front-end.
  - The burn() function removes tokens from circulation and emits an event.
  - The backend monitors the blockchain for the burn event and triggers a manual or automated payout from the EMI.

Tokens are locked or burned on-chain before fiat is released, ensuring irreversibility and preventing double claims. This model prioritizes simplicity and control in early phases (manual weekly transfers), with a roadmap to fully automate reconciliation and payout through EMI API integration and real-time webhooks.

For the cap enforcement the total token supply must always be backed by off-chain fiat reserves. This is enforced via a mintCap variable:

- In the POC, the cap is manually updated by the contract owner using setCap().
- In the MVP, the backend signs cap update messages (EIP-712), reducing on-chain admin exposure.
- In Production, an on-chain Oracle module (with multisig approval) automatically updates the cap based on real-time EMI account balances and/or proof-of-reserve attestations.

Access control and permissions are handled using OpenZeppelin's AccessControl and Ownable patterns, the system defines:

- *MINTER_ROLE:* assigned to backend wallet or licensed mint controller.
- *GOVERNANCE_ROLE*: reserved for upgrades, cap changes, and contract pausing.
- *PAUSER_ROLE*: allows freezing mint/burn in emergency cases.

Operational flow by phase:

- POC:
  - Manual fiat confirmation via EMI dashboard.
  - Back-end manually calls mint.
  - Cap set manually.
  - Burn event triggers manual refund weekly.

- MVP:
  - Real-time EMI API integration.
  - Automated backend minting post-deposit.
  - Signed cap updates.
  - Burn triggers automatic via EMI payout API.
- Production:
  - Regulated mint controller or EMI handles minting.
  - Cap enforced via proof-of-reserve oracle.
  - Dual control or multisig for mint authorization.
  - Real-time payout confirmation, receipts stored on-chain or hashed.

This architecture ensures regulatory alignment, improves transparency, and isolates risk across layers. Additionally, it allows the smart contract logic to remain minimal and auditable, while the off-chain orchestration layer evolves independently with institutional partners.

5.2.3 Governance contracts & Upgradeability

Stableo's governance and upgradeability framework is designed to ensure a high degree of security, flexibility, and operational oversight. The architecture separates smart contract logic from governance decision-making, enabling transparent and accountable system evolution without compromising user trust or decentralization goals. Stableo follows a defined upgradeability pattern where smart contracts are deployed using the proxy upgrade pattern (OpenZeppelin's UUPS or Transparent Proxy), allowing for improvements or bug fixes without requiring a token migration. This mechanism ensures:

- Immutable token addresses: The ERC-20 Stableo token address remains constant, preserving ecosystem integrations and wallet compatibility.
- Isolated logic upgrades: Implementation contracts can be modified without redeploying the entire contract suite.
- Auditability: Upgrade events are transparent and can be tracked on-chain through governance logs and proxy admin events.

Only authorized roles are permitted to initiate upgrades, and upgrade functions are protected by a time delay and multisig controls in production environments. The smart contract suite defines role-based governance to minimize centralization risk and ensure clear separation between operational and strategic powers. The primary roles are:

- Governance role: Holds the authority to update critical parameters such as minting cap (setCap()), pause/unpause operations, and initiate contract upgrades.
- Minter role: Assigned to the backend hot wallet (POC/MVP) or regulated mint controller (Production). This role is responsible for minting after fiat deposit verification.
- Pauser role: Can halt minting and burning in case of emergencies, incidents, or suspicious flows.
- Oracle role (future): Responsible for pushing verified reserve data on-chain or authorizing oracle data feeds.

In early phases, these roles may be consolidated under a backend-controlled multisig. However, production deployment aims for more decentralized governance through a staged approach:

- POC & MVP phases:
    - Governance handled by a 2-of-3 multisig controlled by the Stableo core team.
    - Minimal upgradeability functions; focus on operational testing and speed of iteration.
- Production phase:
    - Transition to a 3-of-5 or 4-of-7 multisig governance model including independent legal, compliance, and technical actors (e.g., board of EMI, technical auditors, co-founders).
    - Emergency pause functions delegated to a smaller subcommittee.
    - Time-lock mechanism introduced for non-urgent upgrades (e.g., 24 – 72 hours), providing transparency and public review period before execution.

Any contract upgrade, including changes to mint logic, cap enforcement, or token metadata, must go through a formal upgrade proposal and review flow from proposal creation which is submitted by a member of the Governance role. Followed by the review phase on publicly visible dashboard or on-chain logs. After time-lock delay and multisig approval the upgrade is initiated.

The system architecture leaves the door open for community governance or off-chain DAO participation in the future, particularly to increase transparency in cap updates, reserve attestations, or oracle configuration. However, in early phases, governance remains tightly scoped to ensure legal compliance and minimize attack surface:

- Emergency control & Revocation. In high-risk or exploit scenarios, designated roles can invoke a *pause()* function to halt minting and burning operations. This function can be invoked by the Pauser or Governance multisig and remains active until the incident is resolved. Access to revoke or reassign roles is tightly scoped to protect against internal compromise.
- Revocation of minting rights (e.g., from a back-end wallet) can also be performed in case of breach or regulator request, ensuring compliance with anti-money laundering and consumer protection standards.

5.3 Off-chain infrastructure

The off-chain infrastructure layer bridges blockchain operations with the regulated financial system. It is designed to ensure robust collateral management, secure and auditable mint/redeem operations, and accurate reserve representation on-chain. This layer plays a critical role in aligning Stableo with MiCAR and PSD2/EMI licensing frameworks by enabling fiat custody, compliance checks, and data integrity. Off-chain infrastructure is built in modular fashion with the goal of ensuring collateral safety and auditability, supporting integration with licensed electronic money institutions (EMIs), enabling automated, yet human-controllable mint and redeem flows and laying the foundation for future integrations with PSPs, exchanges and regulators.

5.3.1 Collateral management & Reserve vault

Stableo reserves are held in euro-denominated accounts at licensed electronic money institutions (EMIs) or banks within the EEA. These accounts are ring-fenced, reconciled daily, and segregated from operational capital.

Key characteristics:

- Custodial safety: Partner EMI or PSP must hold e-money licenses under EMD2 or PSD2 frameworks and maintain 1:1 *euro* backing.
- Auditability: Bank statements or EMI APIs must allow automated reconciliation, and permit generation of verifiable reserve attestations.
- Segregation: Reserves are separated per customer or per stablecoin issuance pool, depending on EMI capabilities.

Stableo does not custody fiat directly; instead, fiat is deposited and held under the EMI's safeguarding rules, with Stableo acting as a tokenization agent. In production, reserves may be placed in highly liquid euro-denominated government securities (e.g. short-term T-bills), generating low-risk yield. However, any such investment must preserve full redemption rights and not compromise on-demand liquidity.

5.3.2 Mint/Redeem flows with EMI partner

Minting and redemption flows are the most sensitive point of integration between off-chain fiat systems and on-chain token issuance. Stableo's architecture separates logic for user interaction, fund reconciliation, and on-chain execution while aligning with legal responsibilities under MiCAR.

- Minting flow:

1) User initiates fiat transfer: via EMI internal transfer to a dedicated IBAN.
2) Back-end reconciliation service: monitors EMI-provided API or webhook to detect incoming transfers, match to user, and confirm KYC compliance.
3) Collateral update: back-end validates whether sufficient collateral is held and pushes updated cap data to the Oracle if needed.
4) Mint authorization: hot wallet or regulated mint controller (in production) issues mint() on-chain for user's wallet address.
5) Audit logging: all mint actions are logged with unique transaction ID, fiat sender metadata, and hash references for audit trail.

Delays can be introduced for compliance review, especially for high-value transfers or suspicious activity. In MVP, reconciliation and minting are automated; in production, optional human oversight can be configured via the backend admin panel.

- Redemption flow:

1) User calls burn() function to trigger token redemption. Tokens are transferred to contract and locked pending fiat transfer.
2) Redemption queue: back-end adds request to outbound payment queue, ensuring AML/CFT checks.

3) Fiat payout initiated: via EMI internal payout. Upon confirmation, release() function is called on-chain to mark completion.
4) Failure handling: in case of payout failure, tokens are returned to the user with full logging of the cause.

Redemption delay is expected (1–3 business days), in line with traditional fiat rails (Stableo ensures same-day redemption, but can't control traditional fiat rails). Weekly manual transfers are possible in early MVP phases; the system architecture accommodates eventual real-time instant integrations as EMI capabilities mature.

5.3.3 Oracle systems (Price feeds & Attestation feeds)

Stableo uses off-chain oracles to publish verified external data to the blockchain. These oracles are a core dependency for mint cap enforcement, collateral tracking, and eventually interest-rate-based mechanisms.

- Reserve oracle
    - Publishes current total *euro* reserves under custody (from EMI API or signed bank statement digest).
    - Updates the smart contract's mintCap parameter via secure signature (EIP-712 or threshold signature).
    - Includes metadata such as timestamp, data source, signer ID.
    - In production, this oracle is operated under a multisig or threshold scheme (e.g. 2-of-3 among backend, EMI, and auditor) to prevent spoofing.

- Price oracle (Optional phase) - if advanced features such as on-chain *euro* bond pricing, collateral allocation, or liquidation thresholds are introduced, price oracles will be used to source:
    - Euro short-term government bond pricing.
    - ECB benchmark interest rates (e.g. €STR).
    - Stableo market price on DEXes (for depeg detection).
    - Integration with Chainlink, Pyth, or custom attestation oracles is planned, with off-chain backup feeds.

5.3.4 KYC & Compliance integration

To comply with European AML and CFT regulations, identity verification and transaction monitoring are embedded in off-chain workflows.

- KYC onboarding: Integration with providers like Onfido or Veriff to handle ID verification and biometric checks. Required before minting access is enabled.
- AML screening: Ongoing transaction and wallet risk analysis via providers like Chainalysis, Elliptic, or internal scoring models.
- Blacklist enforcement: Smart contract integrates blocklist addresses published by backend or compliance provider.

All user actions are tied to internal IDs rather than wallet addresses, preserving user privacy while maintaining traceability under regulatory obligations.

5.3.5 Operational dashboard & Admin controls

A dedicated operational dashboard provides interfaces for compliance officers, support staff, and governance members. Features include:

- Real-time reconciliation of reserves and mint cap.
- Manual override tools for minting, burning, or pausing flows.
- Logs of KYC status, redemption queues, and transfer history.
- Alerts for mismatches, failed payouts, or audit flagging.
- This dashboard also serves as a centralized compliance cockpit for EMI partners and internal teams to coordinate.

This section outlines the essential off-chain infrastructure and its integration with licensed EMIs, which together enable Stableo to function as a fully collateralized, legally compliant euro-backed stablecoin. At the core, this infrastructure ensures that every minted token corresponds to verifiable fiat collateral held in safeguarded EMI accounts, with minting and burning actions strictly gated by compliance and reconciliation workflows. The system incorporates real-time reserve tracking, KYC/AML enforcement, fiat transaction monitoring, and smart contract-bound oracles that reflect verified off-chain data on-chain. This hybrid model bridges the reliability of traditional banking infrastructure with the transparency and programmability of blockchain. It balances operational security with regulatory requirements, enabling automated issuance while preserving auditability and user safeguards. As the system evolves, it can scale through deeper integrations with PSPs, instant SEPA providers, and modular oracle networks — allowing Stableo to grow its utility across DeFi, payments, and institutional settlements without compromising on trust or compliance.

Main considerations:

- Secure custody of fiat reserves under EMI licensing and daily reconciliation standards.
- Real-time, verifiable synchronization between fiat and token supply via oracles.
- Compliance-first architecture for onboarding, KYC, and AML monitoring.
- Flexibility to scale from MVP flows to regulated production-grade processes.

Potential issues are expected and should be mitigated:

- SEPA latency & friction: Minting/redemption may face delays due to traditional banking rails (1–2 business days).
- API or EMI instability: System heavily depends on availability and stability of EMI APIs for real-time reconciliation.
- Operational complexity: Coordinating backend, EMI, and oracle updates introduces risk of mismatches or downtime.
- Security exposure: Backend infrastructure and hot wallets introduce attack surfaces that must be tightly secured.

- Regulatory bottlenecks: Any lapse in KYC, audit trail, or reserve attestation may put operations at risk under MiCAR.

Mitigation & Opportunity paths:

- Redundancy in EMI/PSP partners: Integrate with multiple EMI accounts to ensure uptime and fallback options.
- Automated monitoring & alerting: Implement observability tools to flag cap mismatches, failed payouts, or reserve discrepancies.
- Multi-layered oracle validation: Use multisig-controlled oracles and timestamping to prevent tampering or stale data injection.
- Progressive automation: Begin with semi-manual flows in MVP with admin oversight, then automate under strict audit logs.
- Instant EMI-native transfers.

5.4 Application layer

Stableo's application layer presents the user-facing and operational interfaces that facilitate secure, compliant, and transparent interactions for end users, partners, and internal teams. Its architecture draws on industry best practices (especially from leading stablecoin platforms like USDC and EUROC) while prioritizing a lean and secure rollout path.

5.4.1 User interface: Website & Wallet integrations

To align with lean, secure strategy, Stableo's POC and MVP will not require a traditional login system. Instead, users will connect via a web3 wallet (e.g. MetaMask, WalletConnect) with transfers and identity handling managed through the EMI backend.

- Frontend: Displays wallet balance, pending mint/redemption status, and key information such as mint fee, network gas, and fiat settlement timing.
- Wallet integration: Users sign a transaction to request minting or burning, minimizing reliance on custom authentication and focusing on blockchain-native flows.
- KYC / onboarding notification: After connecting a wallet, users are guided through KYC via DeepLink or embedded iframe served by the EMI partner.
- Security & UX: By avoiding passwords and relying on secure wallets, attack surfaces and operational liability is reduced.

This design mirrors leading stablecoins like USDC, which rely on partner KYC and fiat management while keeping blockchain interactions lightweight and wallet-based. This ensures regulatory compliance while keeping frontend architecture minimal and secure.

5.4.2 API services for Third-parties

Stableo's MVP and beyond will offer tokenized *euro* access via APIs, enabling fintech platforms, wallets, exchanges, and SaaS providers to integrate Stableo mint and burn flows natively into their apps.

- RESTful API exposed over HTTPS/TLS:

    - /mint-request: Issues unique reference, amount, and user wallet.
    - /burn-request: Initiates stablecoin redemption linked to IBAN.
    - /webhooks/deposit-confirmed: Notifies service of EMI deposits to trigger on-chain mint.
- Security:
    - Strong authentication (OAuth 2.0 / JWT).
    - IP whitelisting, rate limiting, and role-based access control.
    - Compliance enforcement (KYC status, AML checks).

This allows lean integration where partners can offer mint/redeem functions without hosting full UI, while Stableo retains compliance and audit logs. Major stablecoins like Circle's USDC and Monerium operate on a similar "API-first" model.

5.4.3 Admin & Compliance dashboards

Stableo's internal tools ensure secure oversight, operational efficiency, and regulatory transparency:

- Mint/redemption monitoring:
    - Real-time view of outstanding requests, tokens issued, and pending payouts.
    - Actionable filters (e.g., high-value requests, flagged wallets).
- Reserve tracking dashboard:
    - Shows on-chain supply vs. off-chain fiat balance.
    - Triggers alerts for mismatches, delays, or low liquidity buffer.
- Role-based tools
    - KYC and compliance review portal powered by EMI and third-party verification providers.
    - Manual override capability for exceptional mint/redemption cases during MVP stage.
- Audit trail & export:
    - Immutable logs of all system actions, accessible for regular MiCAR reporting and external audit.

This visibility and control framework is essential for compliance with the EU regulations and mirrors the controls exercised by licensed fintech and stablecoin operators.

For early iterations, building a custom login system will be avoided. Instead, focusing on wallet-based access for users and partner-API access for integration. Authentication and KYC responsibility are offloaded to the EMI partner, reducing development burden and accelerating time to market. The user flows rely on MetaMask and on-chain interactions, with mint/redemption gated by EMI-confirmed proving of identity and *euro* transfer while partner integrations use secure API credentials, obviating the need for public user accounts. This design follows proven stablecoin models: wallet-led user access and API connectivity managed by the issuer while retaining full regulatory control while delivering a lean and secure product. Stableo's application layer provides secure, regulated, and low-friction user journeys while enabling scalable partner integrations—all without the overhead of building first-party identity systems. This creates a robust foundation for rollout and future expansion.

5.5 Security & resilience

Stableo's architecture embeds layered defenses and fail-safe strategies aimed at protecting user assets, ensuring system stability, and preserving compliance under adverse scenarios. This section describes mechanisms for contract security, key governance, and emergency response.

5.5.1 Smart contract audits & formal verification

Security audits are integral to Stableo's development lifecycle, beginning with a focused evaluation during the MVP phase and culminating in formal verification and regular penetration testing in production.

Audit phases:

- Pre-deployment review of core mint/burn/cap contracts by a leading blockchain security firm.
- Post-audit revalidation following code updates that are essential after adding proxy modules, oracles, or fee logic.
- Formal verification (production) using tools like Certora or CertiK for critical contract invariants, ensuring totalSupply ≤ mintCap, single-phase upgradeability safety, and permission checks.

Security is built using best practices by ensuring minimal contract footprint in early phases to reduce attack vectors. From controlled use of external dependencies (e.g., core libraries like OpenZeppelin) to inclusion of test suites with coverage on edge cases such as reentrancy, overflow, oracle failures, and role misassignment and security logging that captures sensitive events (pauses, caps, upgrades). These practices mitigate risks and help build confidence both among institutional users and regulators by showcasing a defensible posture aligned with industry norms.

5.5.2 Key management & Multisig governance

Secure private key governance is critical to protecting minting and upgrade functions. Stableo applies progressively sophisticated key management approaches:

- MVP phase:
  - Back-end hot wallet keys held securely (e.g., Azure Key Vault or HashiCorp Vault).
  - Cold safekeeping of backup seed phrases, protected with multi-factor authentication (MFA).
  - 2-of-3 multisig wallet (Gnosis Safe) controls reserve proxy and mint permissions.
- Production phase:
  - Hierarchical key management where minting, pausing, and contract upgrades are separated across distinct multisig wallets.

    - Use of hardware security modules (HSMs) for private keys requiring high assurance (EU Cybersecurity Certification Framework (EUCC) or US's FIPS 140-2).
    - Periodic "key rotation" to remove stale or compromised keys.
    - Documentation of role assignments and changes stored with audit logs.
- Access controls:
    - Multisig threshold prevents any single compromise from enabling unauthorized mint/burn actions.
    - Emergency access controls engage only under officially declared events.

This ensures that minting and governance operations follow the "principle of least privilege" and maintain resilience against physical, operational or supply chain threats.

5.5.3 Circuit breaker & Emergency mechanisms

Stableo incorporates crisis management safeguards to protect users in the event of market disruptions, oracle failures, or malicious activity.

- Circuit breakers can automatically halt minting and/or burning when:
    - Oracles feed inconsistent reserve data,\Large unexpected mint/redemption spikes occur,
    - Critical thresholds are breached (e.g., collateral ratio < 100%, a discrepancy between on-chain supply and fiat reserves).
- Emergency pause mode:
    - Activated by authorized multisig signatories.
    - Globally prevents mint and burn actions until issues are triaged.
    - Requires formal "unpause" governance following security review.
- Upgrade rollback:
    - In case of failed or malicious upgrade, multisig reversal or patch deployment can restore previous state.
    - Upgrades are shielded by time delays to allow public review and community participation (where applicable).

These mechanisms ensure that system continuity is protected and any threat can be contained before affecting user funds or protocol integrity. Combined, these elements create a layered security posture including pre-deployment guardrails via audits and formal verification, secure key governance reinforced by HSM-backed multisign setups and on-chain defensive logic enabling safe operation even in edge or failure conditions. With this architecture, Stableo achieves both proactive risk reduction and reactive resilience aligned with financial-grade standards and MiCAR expectations.

5.6 Compliance & integrations

Stableo is built with a compliance-first design, ensuring full alignment with the EU regulatory standards such as MiCAR, AMLD and GDPR. This involves structured integration with third-party

KYC/AML services, audit-ready financial recordkeeping, and transparent reporting for supervisory authorities.

5.6.1 KYC/AML provider integration

To ensure that only verified users can mint or redeem Stableo, all flows must interface with a licensed EMI's identity infrastructure or an external compliance provider:

- User onboarding: Performed by the EMI partner or a compliant third-party (e.g. Veriff, Sumsub), verifying identity, source of funds, and risk profile.
- Minting & redeeming: Back-end validates KYC status via API before allowing on-chain actions.
- Status caching: KYC results are cryptographically signed and cached with a short TTL to prevent overuse of third-party services and ensure frontend responsiveness.
- Compliance tiers: System can support tiered user roles (e.g. retail vs institutional) for applying different mint/redeem limits or reporting thresholds.

A compliance log is maintained for every user interaction tied to KYC identifiers (without storing PII on-chain), preserving privacy while supporting auditability.

5.6.2 Off-chain accounting & Reporting

All off-chain asset flows (user deposits to EMI or treasury reserve management) must be traceable, reconciled, and accountable through real-world financial systems:

- Ledger mirroring: The back-end maintains an internal ledger mapping on-chain balances to user fiat deposits.
- Daily reconciliation routines ensure that fiat inflows match minting activity.
- Reserve balance tracking: Combined reporting of:
    - Total fiat held in EMI accounts,
    - Amount minted on-chain,
    - Buffer or surplus funds (e.g. interest earned, unreconciled redemptions).
    - Audit-ready exports: CSV or JSON exports are generated daily/weekly, with hash-stamped versions stored immutably on-chain or in tamper-proof logs.

In the production phase, third-party financial auditors or EMI-side compliance teams can access this information via read-only APIs or secure data portals.

5.6.3 Audit trails & Regulator reporting

Stableo's backend system and blockchain contracts are designed to produce complete, regulator-facing audit trails.

- Event logging:
    - All mint, burn, cap changes, and oracle updates are emitted as indexed on-chain events.
    - Off-chain activities (KYC passes, fiat flows) are recorded in append-only logs.

- Regulatory interfaces:
  - APIs compatible with reporting schemes like MiFIR, EMIR, or 8th EU Directive on Administrative Cooperation (DAC8) where relevant.
  - Scheduled disclosures (e.g. quarterly minting stats, counterparty risks) can be auto-generated.
  - Emergency freeze triggers and access logs for pausing or multisig actions are exported and signed.
- Proof of Reserves:
  - On-chain publication of EMI account attestations (via oracle or direct EMI notarization) with timestamps and signatures.
  - Users and regulators can compare totalSupply() vs attested reserve amount at any time.

This infrastructure provides technical guarantees of transparency while reducing regulatory friction and demonstrating maturity to institutional partners.

5.7 Interoperability & Integration layer

The interoperability layer defines how Stableo connects with external wallets, fiat on/off-ramp providers, exchanges, and analytics ecosystems. Building interoperability in phases (from minimum viable integration to full partner embeddability) aligns with our lean vision while preparing for robust, institutional-grade utility.

5.7.1 Wallet & fiat on-ramp integration

Stableo's initial on-chain access will rely on standard Web3 wallets such as MetaMask and WalletConnect. Users will connect their wallet and initiate mint or burn requests directly, while fiat/currency transaction flows are handled by our EMI partner in the back-end. This flow allows us to avoid building custom login systems and simplifies compliance by leveraging wallet-based identity flows paired with external KYC handled by the EMI.

To reduce friction, WalletConnect's on-ramp software development kits (SDKs) (including Coinbase On Ramp or Alchemy Pay support) may be integrated in MVP to enable in-app fiat-to-token conversion in partner environments. These solutions allow embedded fiat payments using credit/debit or bank transfers, delivering tokens directly to connected wallet addresses (much like major stablecoin providers offer).

These integrations provide flexibility:

- MVP:
  - wallet connection and simple mint/burn UI, funds handled off-chain manually or via EMI API.
  - embedded on-ramp flows using third-party SDKs (e.g. Alchemy Pay, Coinbase On Ramp).

- Production:
  - self-hosted or integrated partner on-ramps via customizable iFrame widgets or API flows.

5.7.2 Exchange & partner onboarding (CEX/DEX Support)

Stableo aims to be listed on centralized exchanges (CEXs) and available in decentralized exchanges (DEXs) across relevant Ethereum Virtual Machines (EVM)-compatible chains. Partner APIs will enable automated bulk minting/redemption flows for liquidity providers, exchanges, payment processors and wallets.

- DEX liquidity: Strategy includes listing on liquidity pools (e.g. Uniswap, SushiSwap) and using bridge aggregators like CoinGecko or DeFiLlama to promote market visibility.
- CEX integration: Institutional partners can obtain tokens directly via API flows, similar to how Circle's USDC and Monerium operate in Europe.

By offering straightforward API endpoints and off-ramp support, Stableo prepares for partnership with traditional financial platforms while preserving regulatory control and auditability.

5.7.3 Cross-chain & Omnichain interoperability

To ensure secure cross-chain interoperability, Stableo will use Chainlink CCIP, which offers a battle-tested, permissionless bridge architecture with Proof-of-Reserve (PoR) functionality and audited on-chain routing. CCIP reduces smart contract exploit vectors and isolates systemic bridge risk compared to monolithic solutions like LayerZero. This is a modular, secure cross-chain protocol supported by:

- Decentralized off-chain execution via Chainlink nodes
- Verifiable Proof-of-Reserve (PoR) attestation before minting
- Built-in fallback logic and rate limits
- Compatibility with external insurance guarantees - this design ensures that €O tokens bridged to other chains are verifiably backed by on-chain reserves and governed by strict thresholds:
  - Max bridged supply per chain
  - Real-time PoR refresh every 10 minutes
  - Bridge halt if collateral delta >1%
  - Proof-of-Burn + Mint logic to prevent replay attacks and enable deterministic supply tracking across chains.

Bridge contracts are upgradeable only via governance quorum and protected by timelock. In case of bridge exploit or oracle desync, fallback is to emergency freeze bridged supply and rebase to the last valid state using Chainlink PoR audits.

The implementation is organized in 2 phases:

- MVP:
  - Focus remains on one chain with future proofing in contract structure.

    - Integrate cross-chain messaging for minting or redeeming on alternate chains using secure endpoints.
- Production:
    - Enable bridged assets on other Layer 2 (L2s) or rollups, with standardized reserve mapping and collateral parity.

This architecture ensures Stableo can adapt to future multi-chain DeFi ecosystems without compromising secure *euro* collateral backing. Integration with third-party on-ramp providers accelerates user onboarding but introduces KYC/API dependencies. At the same time cross-chain protocols add interoperability but increase smart-contract complexity and audit surface which must account for regulatory compliance and on-chain proof-of-reserve alignment.

Fiat on-ramp reliability will be mitigated by choosing high-trust providers and fallback EMI channels and integrations must be secured by layering across multisig, ensuring oracle safety, and upgradable contract design. Adding additional channels increases regulatory complexity as each partner integration (WalletConnect, exchanges) must comply with MiCAR, EMI, and local AML regulations. Stableo's interoperability strategy ensures user access, partner integrations, and future scalability are structured in stages, balancing lean delivery with flexibility for adoption across wallets, platforms, and blockchains.

5.8 Tokenomics & Incentives

Although Stableo is a non-inflationary stablecoin with strict 1:1 *euro* backing, tokenomics still play a critical role in shaping user behavior, sustainability of operations, and long-term ecosystem alignment. While minting and holding Stableo is free of inflationary rewards by design, optional incentive mechanisms are introduced to drive adoption, reward specific actions, and build a self-sustaining treasury.

5.8.1 Incentive mechanisms for adoption

In the absence of yield-bearing inflation, incentives must be carefully engineered to remain economically sound while encouraging liquidity, trust, and utility. First, institutional minters (e.g., fintech platforms or eurozone stablecoin distributors) can be offered volume-based rebates. For example, to encourage onboarding and higher transaction volumes, entities minting more than €5 million worth of Stableo within a given calendar quarter may qualify for a transaction rebate of 0.05%. This rebate is a one-time commercial discount applied to minting fees and is not linked to the length of time Stableo is held. Rebates may be paid in *euro* or Stableo and are funded from a designated treasury incentive pool. The rebate functions strictly as a volume-based discount mechanism, comparable to fee reductions in payment networks, and does not constitute interest, yield, or any form of remuneration on token holdings.

Second, zero-fee redemptions or fee subsidies for high-frequency use cases (e.g., payroll, merchant payouts) can be trialed as part of pilot programs. This targets real economic activity over speculative trading. Statistical modeling suggests that even a small €10,000/month user base using Stableo for monthly salaries could result in significant organic network growth without inflating the token.

Third, partnerships with wallets, exchanges, and fintech platforms may involve co-funded campaigns, where Stableo subsidizes user acquisition costs. For example, providing a one-time €5 in Stableo upon onboarding a verified user. Behavioral incentive theory shows that small upfront incentives drive 3x-5x higher retention when compared to delayed rewards.

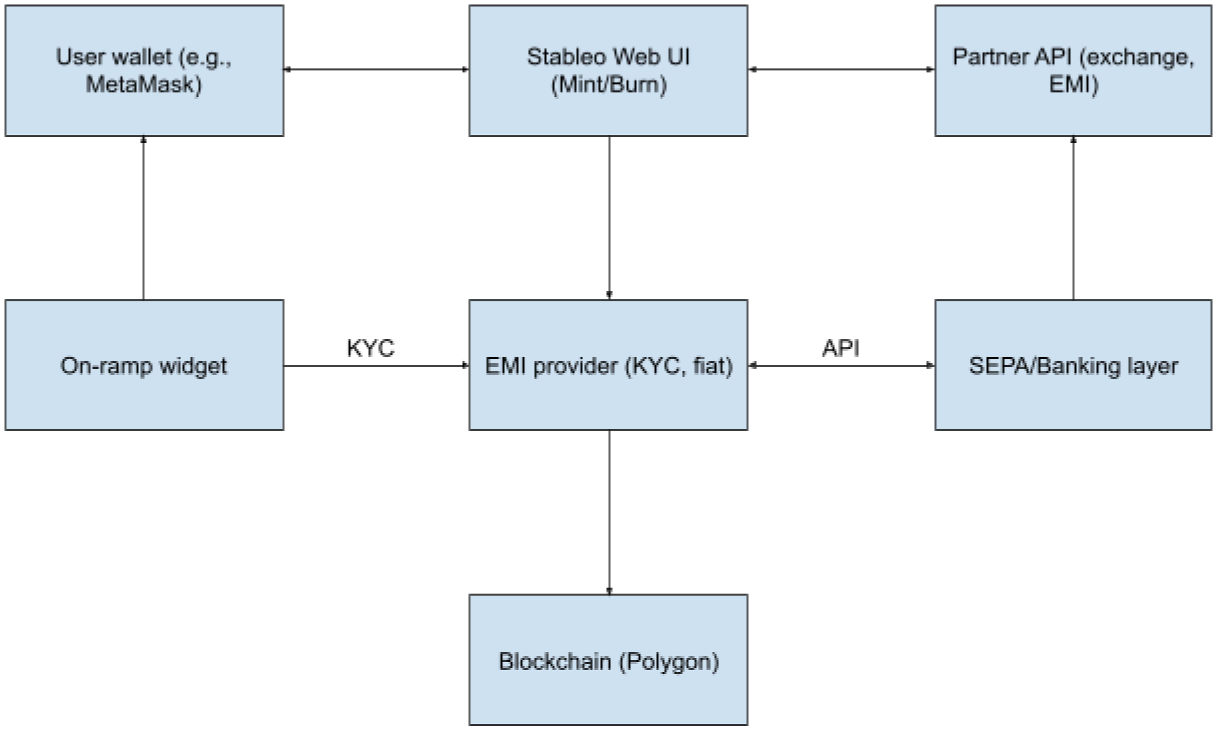
Fourth, a "fee-sharing" scheme can be considered for liquidity providers or fiat on/off ramp partners. For instance, a 0.1% redemption fee can be split 70/30 between the protocol treasury and the integrated exchange, creating mutual value and onboarding incentives. This is especially valuable if the protocol moves toward permissioned liquidity pools or white-labeled exchange rails.

Fifth, governance privileges and early whitelisting can be offered to ecosystem contributors and early liquidity providers. Even though Stableo is not yield-bearing, access to governance, treasury use decisions, or fee allocations can become meaningful once adoption scales. These rights can be non-transferrable non-fungible tokens (NFTs) or soulbound tokens (SBTs), reducing risk of regulatory classification as securities.

5.8.2 Treasury accumulation & Buffer strategy

As there is no seigniorage (minting profit) in a 1:1 fiat-backed model, the protocol must generate operating funds via limited and non-distortive mechanisms. A primary strategy is to collect protocol fees (e.g., 0.1% on redemptions, capped annually), which are routed into a Treasury Buffer Vault. This vault acts as an operational reserve to fund audits, oracles, bug bounties, and future upgrades.

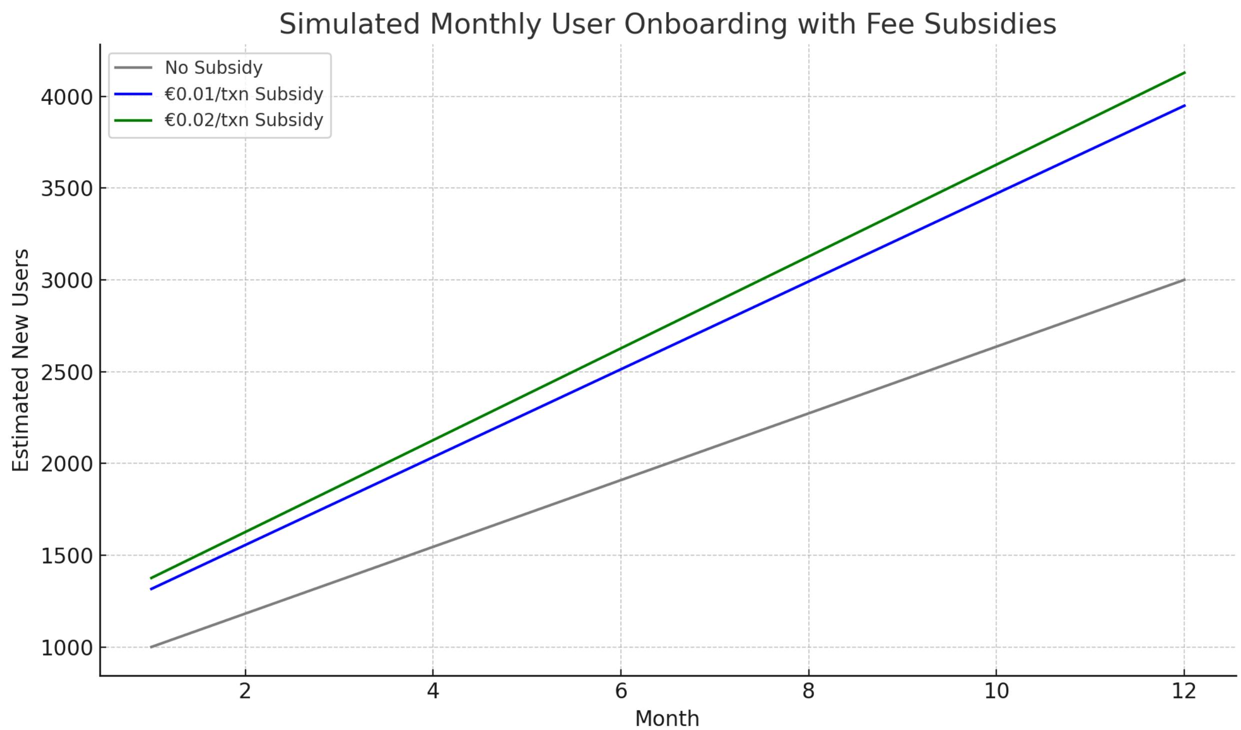
A model scenario: if the protocol processes €50M in redemptions per year with a 0.1% fee, that results in €50,000 in protocol revenue. With fee-free minting and only redemption fees, user friction is minimized. These funds can be invested in short-term euro-denominated government bonds (EEA-compliant), yielding a modest 2%-3% annualized return, which adds to the treasury buffer and partially subsidizes platform costs.



5.8.3 Cost subsidization modeling

To further reduce user costs, particularly during bootstrapping, the protocol may run subsidized mint or redeem phases, where early adopters receive a rebate on fees or transaction costs. This is viable via finite treasury allocations. For example, if a €100K launch fund covers up to €10K in transaction fee subsidies, it can allow ~500,000 user transactions at €0.02 cost offset per operation, improving UX and perception significantly.

Modeling simulations show that user onboarding increases non-linearly with transaction fee subsidies (initial cost offsets in the first 12 months can increase retention and daily active usage by over 20%, especially when targeting friction-sensitive B2C segments like remittances or payrolls).



Modeled monthly user onboarding over a 12-month period under different transaction fee subsidy levels (€0.00, €0.01, €0.02). The core assumption is that user adoption increases non-linearly with fee subsidies (small cost reductions lead to disproportionately higher engagement due to reduced friction, especially in price-sensitive segments like payroll or remittances):

- Baseline onboarding (no subsidy): Assumes linear growth from 1,000 to 3,000 new users/month.
- Uplift modeling: A power-law response function (uplift ~ subsidy^0.25) represents behavioral elasticity (small subsidies create a measurable increase in onboarding).
- Sensitivity: The exponent 0.25 is derived from empirical models in fintech studies (e.g., fee elasticity in mobile banking adoption).

For example:

- A €0.01 subsidy increases total onboarding by ~11% over baseline.
- A €0.02 subsidy results in a ~22% total increase in user onboarding.

This modeling supports a strategy of subsidizing transaction costs early on to boost network effects and usage, which can later taper off as organic growth and trust mechanisms (like reputation or security guarantees) take over. Customer Acquisition Cost (CAC) can be modeled as well:

- Subsidy-only model:
    - Subsidy cost/user/month = €0.02 × 5 tx = €0.10/month
    - Over 12 months: €1.20/user
    - Total CAC = €4 (avg) + €1.20 subsidy = €5.20/user
- Lifetime value (LTV) model:

    - Gross revenue per user/month = 5 tx × €0.015 = €0.075
    - Over 24 months: €0.075 × 24 = €1.80
    - Optional redemption fee (0.1% of €200 avg redemption/month) = €0.20/month results in €4.80 over 24 months
    - Total LTV = €1.80 + €4.80 = €6.60/user

- Profitability ratio (LTV/CAC): LTV/CAC = €6.60 / €5.20 ≈ 1.27

Retail users interact with Stableo via exchange partners, wallets, or neobank apps, where KYC/AML is handled externally (not directly by Stableo). This mirrors the operational model of USDC or USDT. Institutional clients (e.g., funds, treasuries) engaging in high-volume mints or redemptions must onboard via Stableo's gateway, completing necessary KYC/KYB/AML processes. However, these clients typically transact in 6–7 figure amounts, making onboarding costs negligible (<0.01% CAC).

This suggests a positive unit economics model even at early stage, with potential to improve as:

- Redemption fees scale
- Subsidies taper off post-onboarding
- Power users emerge
- Subsidies to be capped for the first 3-6 months per user to improve LTV/CAC quickly.
- After a 3-6 month period dynamic fee tuning should be enabled gradually reducing subsidies for repeat users, rewarding stable balances instead.
- Subsidies focused on high-volume cohorts (e.g., remittance partners, payroll processors).
- Subsidies should be funded via interest on float/bonds to reduce net cost.

Stableo does not reward token holding via yield, maintaining clarity of its 1:1 peg and regulatory simplicity. Other solutions can be chosen to increase interactions with the coin like optional redemption fees up to 0.1% to fund operations, institutional volume rebates or other strategic campaigns to stimulate ecosystem growth in a controlled, measurable manner. These principles ensure that Stableo remains cost-efficient, trustworthy, and aligned with EU financial integrity expectations, while offering just enough flexibility to support adoption and operational sustainability.

6. Regulatory compliance (MiCAR)

6.1 MiCAR alignment

Stableo is designed as an asset-referenced token (ART) fully aligned with Articles 36 – 42 of the Markets in Crypto-Assets Regulation (MiCAR). As such, it adheres to all requirements applicable to ART issuers, including reserve backing, redemption rights, disclosures, governance standards, and operational safeguards.

Key Compliance components:

- Segregated reserves (Bankruptcy-remote)**:** All reserves backing Stableo are held in segregated custodial accounts that are legally structured to be bankruptcy-remote. This ensures holders maintain priority rights over reserve assets in the event of issuer insolvency.

- 1:1 redemption in *euro*: Token holders are entitled to redeem Stableo at par value (1:1 in *euro*) directly through the issuer or authorized distributors, subject to standard KYC/KYB/AML verification.

- Transparency and disclosure: All information required under MiCAR, including reserve composition, operational risks, governance arrangements and redemption procedures, will be fully disclosed and publicly available through the whitepaper, website and periodic reports.

Governance framework: Stableo's governance structure follows the EBA Guidelines on Internal Governance of ART Issuers[26]. It includes:

- A clearly defined and accountable management body;
  Independent internal control functions (risk management, compliance, and internal audit);
- Policies for fit-and-proper assessment of key function holders;
- Defined procedures for conflict of interest management and whistleblowing;
- Adequate oversight of any outsourced functions[27].

Cybersecurity and operational resilience, Stableo will implement:

- Secure IT access protocols, cryptographic key management, and internal access controls;
- Incident response plans and periodic resilience testing aligned with the EU Digital Operation Resilience Act (DORA) framework;
- Regular evaluation of system security risks and mitigation protocols.

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[26] EBA Final Report: Guidelines on Internal Governance for Issuers of Asset-Referenced Tokens (June 2024)
[27] Ibid., Sections 4–7: Governance arrangements, control functions, fit-and-proper assessment, and outsourcing

Transparency and disclosure: All information required under MiCAR, including reserve composition, operational risks, governance arrangements, and redemption procedures, will be publicly disclosed through the whitepaper, website, and periodic reports.

Stableo aims to exceed baseline MiCAR expectations by integrating real-time blockchain disclosures and independent audit attestations.

6.2 Licensing path

Stableo will follow a phased approach to achieving full MiCAR licensure as a crypto-asset issuer in the European Union, starting from the Baltic region.

- Phase 1 – regulatory sandbox participation: Stableo is actively engaging with Latvijas Banka, the competent supervisory authority in Latvia, to participate in its regulatory sandbox. This phase allows us to validate the Stableo model in a controlled environment, including reserve architecture, redemption mechanics, and investor protection protocols, in close consultation with the regulator.

- Phase 2 – MiCAR License application: Following the sandbox consultation, Stableo will submit a formal application to become a licensed crypto-asset issuer under MiCAR, pursuant to Articles 36–42. The application will include a compliant whitepaper, reserve backing policies, governance documentation in line with the EBA Internal Governance Guidelines, and appointment of a compliance officer and AML/CFT procedures under Article 15 of MiCAR and EBA sectoral guidance on crypto-assets[28].

Our legal and governance structure is being developed in coordination with local counsel and aligned with MiCAR Title III obligations on crypto-asset issuers. This phased approach allows for early supervisory engagement and risk mitigation prior to full-scale issuance.

6.3 Disclosures and reporting

Stableo is committed to transparency, consumer protection, and regulatory accountability through multi-layered disclosure and reporting practices.

Daily on-chain proof-of-reserves: On-chain attestations using Merkle proofs verify that the circulating token supply does not exceed the value of euro-denominated sovereign bond reserves held in custody. These attestations are updated daily and publicly accessible.

Monthly attestations: Independent audit firms (MiCAR-eligible) will issue monthly attestations verifying reserve holdings, redemption coverage ratios, and compliance with MiCAR operational requirements.

Quarterly reporting: Stableo will publish quarterly reports including:

[28] EBA Guidelines on AML/CFT Compliance for Crypto-Asset Service Providers, June 2024.

- Detailed reserve asset composition by issuer, jurisdiction, and credit rating;
- Weighted average maturity and interest rate sensitivity;
- Redemption activity and liquidity coverage ratios;
- Business continuity and IT security reports (per Article 37(2)(e) of the MiCAR);
- Any changes to custodians, governance structure or risk management policies.

Whitepaper compliance: Stableo's whitepaper will follow the format and disclosure mandates of the ESAs' Article 97 Guidelines[29], including:

- Investor rights and risk factors;
- Legal and regulatory classification;
- Complaints handling mechanisms;
- Public commitments on redemption and disclosures.

By adopting a robust reporting structure, Stableo aims to build investor confidence, align with supervisory expectations and demonstrate regulatory maturity.

[29] Joint ESAs Final Report on Article 97 Guidelines under MiCAR (ESMA34-607-3176), December 2024.

7. Roadmap & Milestones

The development and launch of Stableo are structured around a phased roadmap that balances operational readiness, regulatory alignment and technological scalability. Each milestone includes clear, measurable actions with realistic timelines that reflect regulatory prudence and stakeholder accountability. This timeline ensures that the issuer can meet MiCAR obligations while engaging the market in a transparent and controlled manner.

Phase 1 — Initial Launch (Simplified Regime, Limited AUM)
Timeline: September 1, 2025 – February 2026

Objective: Deploy MVP under a regulatory sandbox in Latvia, validate operational model, and prepare for full MiCAR licensing.

Key Activities:

- Weeks 1 – 8:
    - Establish EU legal entity (Latvia)
    - Apply for regulatory sandbox / PI-EMI registration
    - Partner with EMI for IBAN issuance and integration
    - Draft legal, AML, governance frameworks
    - Develop backend MVP (mint/burn logic, compliance dashboard) and test internally
- Weeks 8 – 16:
    - Soft launch with capped AUM (e.g., <€5M)
    - Public read-only dashboard & internal audit tools
    - Onboard first users (manual KYC, embedded wallet)
    - Partner API integrations for wallets and CEX
- Weeks 16 – 24:
    - Daily on-chain/off-chain reserve reconciliation
    - Monthly internal reserve attestations
    - Automated cap updates from reserve data

Expected outcome: Functional MVP in live environment, initial user base, verified operational processes.

Phase 2 — Full MiCAR-compliant launch
Timeline: March 2026 – October 2026

Objective: Obtain full license, remove AUM limits, and expand product capabilities.

Key Activities:

- March – May 2026: Submit full PI/EMI or ART issuer application with comprehensive documentation (governance, AML/CFT, IT security, business plan, audited financials).

- June – October 2026: Engage in regulatory review, adjust documentation, secure license, launch mainnet, integrate APIs with CEX/DEX partners, enable real-time payouts, deploy eurobond ladder portfolio.

Expected outcome: Fully licensed operations under MiCAR, scalable infrastructure, and expanded partnerships.

Phase 3 — Post-licensing scaling
Timeline: November 2026 onward

Objective: Grow ecosystem integrations, enhance liquidity, and maintain regulatory transparency.

Key Activities:

- Monthly third-party reserve attestations
- DeFi liquidity provision across ≥5 protocols
- Governance and audit team expansion
- Routine MiCAR reporting

Supporting Documentation (with indicative preparation timelines):

- Corporate & Governance manual – week 4 draft
- AML/CFT & KYC handbook – week 6
- Treasury & Reserve policy – week 8
- Operational security & Continuity plan – week 10
- IT & Data privacy architecture – week 12
- Business plan & Capital forecast – early draft, refined continuously

8. Risk management

8.1 Overview of Risk management framework

The Issuer has implemented a proportional and risk-based framework to identify, assess, monitor, and mitigate risks arising throughout the lifecycle of the asset-referenced token, Stableo. This risk management system is fully aligned with Title III of MiCAR and the EBA Guidelines on Internal Governance, and it aims to ensure financial soundness, operational resilience, and the protection of token holders as well as the resilience of our project.

The risk management framework covers the following key categories:

- Liquidity, redemption and peg risk: Daily mark-to-market valuation of sovereign bond reserves ensures accurate asset backing. Liquidity stress tests assess redemption readiness under various stress scenarios.
- Market and interest rate risk: Weighted average maturity and sensitivity to rate changes are continuously monitored and reported.
- Credit and concentration risk: Reserve composition is managed to ensure diversification across jurisdictions, issuers, and credit tiers.
- Technology, operational and cybersecurity risk: Systems and processes are subject to business continuity testing and incident response readiness under Article 37 of the MiCAR.
- Regulatory and compliance risk: The management body oversees the risk control function, which operates independently from business operations.

To support transparency and accountability, the following controls are in place:

- Daily mark-to-market valuation of all backing assets;
- Public attestation of reserves by an eligible, independent audit firm;
- Annual scenario-based stress testing across liquidity, market, concentration, and operational risks.

Risk governance is overseen by a designated Risk Officer and is regularly reviewed by the Management board and internal audit function. The risk management system will be continuously adapted to reflect regulatory expectations, token adoption, and market dynamics.

8.2. Risk governance structure

The Issuer has established a clearly defined risk governance structure in line with the best practices regarding internal governance of the Issuer. The management body has ultimate responsibility for approving and periodically reviewing the overall risk strategy and ensuring the effectiveness of the risk management framework.

A dedicated person representing a risk management function, independent from revenue-generating functions, is responsible for the day-to-day oversight of risk identification, assessment, and reporting. This person reports directly to the Management board and coordinates with the compliance and internal audit functions.

The risk function is supported by documented risk policies, defined risk appetite thresholds, and regular training for key personnel. Changes in risk exposure or breaches of risk limits are promptly escalated and addressed under a documented governance process.

8.3. Stress testing methodology

In accordance with Article 45 (1)(c) of the MiCAR, the Issuer conducts annual scenario-based stress tests to assess the resilience of Stableo's reserve composition, liquidity profile, and operational setup under extreme but plausible conditions.

The stress testing framework includes:

- Shocks to bond prices due to interest rate volatility;
- Simultaneous mass redemptions over short timeframes;
- Failure of custodians or operational counterparties;
- Technology disruptions affecting issuance and redemption;
- Market dislocation events impacting reserve liquidity.

Results of the stress tests are reviewed by senior management and used to recalibrate risk limits and liquidity buffers. A summary of key findings is disclosed in quarterly and annual reporting, subject to supervisory review.

8.4. Risk escalation and Incident reporting

In accordance with Article 37 (4) of the MiCAR, the Issuer has implemented procedures for the timely escalation of material risks, breaches, and incidents. Internal reporting mechanisms ensure that relevant control functions and management are notified without undue delay.

Where required, material ICT-related incidents, operational disruptions, or systemic reserve issues will be reported to the competent authority. The escalation protocol includes defined thresholds for internal alerts, categorization of incident severity, and documentation of remediation actions.

A whistleblower channel is available for internal and external stakeholders to report control breaches confidentially, in compliance with applicable regulatory acts on whistleblower protection.

8.5. Identified risks

The Issuer has conducted a comprehensive risk assessment in accordance with the Markets in Crypto-Assets regulatory framework and the EBA Guidelines on Internal Governance. The following categories represent the primary risks associated with the issuance and operation of the asset-referenced token Stableo. Each risk category includes representative events and the risk mitigation measures implemented to ensure stability, resilience, and protection of token holders.

8.5.1 Market risk (mainly interest rate risk)

Description: Exposure to changes in market conditions, particularly interest rate volatility, which may affect the valuation of backing sovereign bonds and indirectly the asset-referenced token.

Risk event: Price volatility of backing assets and token; interest rate spikes causing devaluation of reserves.

Mitigation: Active portfolio management, mark-to-market accounting, interest rate sensitivity reporting, listing on multiple exchanges, use of professional market makers, and investor disclosures.

8.5.2 Credit risk

Description: Risk of default by counterparties such as bond issuers, custodians, or financial service providers.

Risk event: Issuer or custodian default; deterioration of bond issuer creditworthiness.

Mitigation: Diversified and high-grade sovereign bond portfolio; counterparty credit scoring; regular solvency reviews; use of regulated custodians; capital buffers and audit oversight.

8.5.3. Technology risk

Description: Risk of failure or vulnerabilities in smart contracts, blockchain infrastructure, or application logic.

Risk event: Smart contract bugs; network attacks (51%, DDoS); protocol errors.

Mitigation: External code audits, formal verification of critical contracts, open-source review, continuous monitoring, and emergency upgrade mechanisms.

8.5.4 Liquidity risk

Description: The risk that an asset can’t be quickly sold or redeemed at its fair value - especially during times of stress - without causing a significant loss. For example, 1) Eurobonds are not instantly liquid, especially in large volumes or during market turmoil; 2) redemption pressure might force the issuer to sell bonds at a loss, breaking the peg; 3) if reserves are locked in fixed-income products, stablecoins may become illiquid during redemptions.

Risk event: Inability to redeem tokens for fiat or collateral due to bottlenecks or liquidity mismatch; limited buyers/sellers may cause high volatility or inability to exit a position; mass sell-offs (e.g., panic, black swan event) causing price crashes or halts in redemption.

Mitigation: Listing on multiple regulated exchanges; weekly/monthly redemption caps; reserve management strategy; holding liquid, high-quality backing assets; stress testing reserve sufficiency; real-time liquidity dashboards (Capitalisation ratio & Liquidity gap) fed by on-chain oracles per CALM methodology[30]; emergency response plans.

8.5.5. Operational risk

Description: The risk of loss caused by failures in internal processes, people, systems or external events. It's about how a company or protocol functions internally. For example: 1) eurobonds must be stored securely. A mistake here could make the collateral inaccessible (custody risk); 2) misreporting the value or structure of reserves could cause the peg to break (accounting risk); 3) If the code managing reserves has a bug or is exploited, funds could be drained (smart contract risk (for DeFi-backed stablecoins)); 4) Operational failures may delay or block users from redeeming their stablecoins for euros (redemption risk).

Risk event: Errors in transaction processing, token issuance or smart contract execution; human error or system downtime; mistakes by team members (e.g., deploying faulty contracts or mishandling private keys); failures or outages by partners (e.g., custodians, oracle providers, infrastructure vendors); downtime in backend systems, APIs or interfaces.

Mitigation: Automated workflows, audit logs and multi-layer approvals for key actions; disaster recovery plans, redundancy systems and staff training; staff training, runbooks, QA protocols and sandbox testing environments; vendor risk assessments, redundancy, and fallback services; SLA-compliant hosting, disaster recovery plans and performance monitoring.

8.5.6 Cybersecurity risk

Description: The threat of unauthorized access, hacking, data breaches and other malicious activities that could compromise the security of the Issuer, asset-referenced token Stableo or its users.

Risk event: Attackers gaining access to hot wallets or user keys; DDoS, API abuse, database injection, or phishing attacks on user-facing applications; internal team members with elevated privileges misusing access; Attackers exploiting vulnerabilities in deployed contracts (e.g., reentrancy, flash loans);

Mitigation: Use of cold storage for treasury funds; multi-signature wallets and hardware security modules (HSMs); regular key rotation; firewalls, DDoS protection and penetration testing; secure

[30] Bluhmetal., "Real-time Risk Metrics for Programmatic Stablecoin (CALM)" (capitalisation & liquidity metrics; automatic buffer adjustments): https://arxiv.org/abs/2401.13399

coding practices and endpoint hardening; role-based access control (RBAC); activity monitoring and audit trails; segregation of duties; independent code audits; formal verification and upgradeable contract design; gug bounties. Nevertheless, the default guarantees alone do not protect holders from cyber events, hence important focus shall be put on AML/CFT controls, taking into account the principle of proportionality.[31]

8.5.7 Redemption risk

Description: The risk the asset-referenced token issuer may not be able to fulfill redemption requests - i.e., return the promised fiat or underlying assets when token holders want to cash out.

Risk event: Operational or liquidity issues prevent timely processing of redemption requests; backing assets are not sufficient or liquid enough to meet redemption demands; centralized redemption interfaces become unavailable (e.g., due to attack or maintenance).

Mitigation: Redemption queueing systems, redemption caps and guaranteed redemption windows; real-time reserve transparency, overcollateralization and liquidity buffers; multi-channel redemption mechanisms (e.g., via smart contracts or partners).

8.5.8 Peg risk

Description: The risk that a stablecoin will lose its intended fixed value (its "peg") - such as €1 for a euro-pegged coin — due to problems in its design, reserves, or market conditions.

Risk event: Imbalance between supply and demand causes deviation from peg; if the backing assets fluctuate in value (e.g., non-cash reserves), the peg may break; oracle errors or manipulation lead to incorrect peg pricing;

Mitigation: Automated supply adjustments, incentives for arbitrage, and liquidity support; holding high-quality liquid assets (HQLA), avoiding unstable or exotic assets; multiple oracles with median pricing, fallback feeds, and circuit breakers.

8.5.9 Concentration risk

Description: The overreliance on a limited number of assets, counterparties, institutions or markets for the backing of the token. For example, all the issuers choose 1 or very few custodians. If any of these concentrated exposures fail or deteriorate, it can pose serious threats to the token's value, stability, and redeemability.

Risk event: Overreliance on a single custodian, oracle, or infrastructure provider; reserves or exposure are heavily weighted toward a single type of asset; too much control in hands of a small team or entity;

Mitigation: Use of multiple service providers and geographic dispersion; diversified portfolios (e.g., cash, government bonds, stablecoins); transparent and decentralized governance models; voting mechanisms.

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[31] https://www.finma.ch/en/news/2024/07/20240726-m-am-06-24-stablecoins/

8.5.10 Regulatory & compliance risk

Description: The risk that a project or company will face legal, regulatory, or enforcement actions that could: 1) restrict operations; 2) require major changes to its structure; 3) lead to penalties or shutdowns; 4) cause loss of user trust or liquidity.

Risk event: Offering may fall afoul of MiCAR or be banned in certain regions; failure to implement appropriate KYC/AML controls where required; conflicting rules between the EU and other jurisdictions.

Mitigation: Ongoing legal review, local legal partnerships and adaptation to local rules; AML policies, KYC/KYB integration with reputable providers and GDPR-compliant data processing; limiting offering to compliant jurisdictions and using geo-blocking where necessary.

8.6. Risk monitoring and response

The Issuer maintains an integrated risk monitoring and incident response system that aligns with Article 33 of the MiCAR and guidance from Latvijas Banka. Key components include:

- Ongoing internal audits of redemption and custody processes;
- Real-time monitoring systems for key risk metrics (liquidity, credit, tech failures);
- Incident escalation procedures and a dedicated for risk management responsible person who reports monthly to the Management Board;
- Public notification of material incidents through official channels within 24 hours;
- Activation of a predefined crisis protocol during risk events, including communication with the competent authority.

Where required, the Issuer will perform supervisory stress testing simulating macroeconomic shocks, redemption runs, and bond market disruptions. Results will be reviewed by the Risk Management Committee and submitted to regulators upon request.

9. Legal and risk disclosures

The Issuer informs every natural and/or legal person that every decision regarding asset-referenced token shall be made using appropriate due diligence. Activities related with Stableo, which is asset-referenced token, whether sending, receiving, using as an investment vehicle or means of exchange are subject to different kind of risks.

Hence the Issuer hereby declares that:

- the asset-referenced token may lose its value in part or in full;
- the asset-referenced token may not always be transferable;
- the asset-referenced token may not be liquid;
- the asset-referenced token is not covered by the investor compensation schemes under Directive 97/9/EC of the European Parliament and of the Council (35);
- The asset-referenced token is not covered by the deposit guarantee schemes under Directive 2014/49/EU.

The management of the Issuer confirms that *Stableo* is asset-referenced token and that this white paper complies with this title. To the best of the knowledge of the management of the Issuer, the information presented in this white paper is fair, clear and does not mislead. The white paper of this asset-referenced token makes no omission likely to affect its import.

The Issuer offers the public asset-referenced token (ART) called *Stableo*. The token is referenced by short-term government bonds of the member states of the European Union which qualifies as investment grade. Investment grade government bonds are of credit rating of BBB- (or Baa3) or higher received from major credit rating agencies: 1) Standard & Poor's (S&P): BBB- and above; 2) Moody's: Baa3 and above; 3) Fitch: BBB- and above. These ratings indicate a low risk of default and are considered suitable for most institutional investors. Ratings can change based on a country's fiscal health, political stability, debt levels and economic performance.

In particular, ART is intended to maintain a stable value by referencing a basket of low-risk, investment-grade EU government bonds. Prospective holders should carefully consider the following information before acquiring or using the ART:

9.1 Nature of the ART

The Asset-Referenced Token (ART) is a euro-denominated digital token issued in accordance with Article 3(1) (6) of the MiCAR. The ART is fully backed by euro-denominated sovereign bonds issued by Member States of the European Union, with a minimum credit rating of A- (or equivalent). The selected bonds are characterized by high liquidity, low volatility, and sound credit quality. All reserve assets are held in segregated, bankruptcy-remote accounts with regulated custodians.

The ART qualifies as an asset-referenced token and is structured to meet the criteria of an e-money token under Article 3 (1) (7) of the MiCAR, offering holders the right to redeem at par in euros at any time.

9.2 Stability mechanism

The ART maintains a stable 1:1 peg to the *euro* through a transparent reserve system. Reserves consist solely of investment-grade sovereign bonds and a liquidity buffer held in euros with Tier-1 EU financial institutions. Independent third-party auditors will verify reserve levels monthly, and real-time attestation mechanisms will be implemented. The issuer employs robust liquidity stress testing and redemption forecasting in accordance with Articles 30 – 34 of the MiCAR.

All reserves are held in instruments eligible under Article 30 (2) of the MiCAR and valued at fair market value using mid-market pricing sourced via independent, regulated data feeds. In redemption events, claims are processed on a first-come, first-served basis unless emergency measures are triggered.

9.3 Reserve composition & Risk

The underlying reserves consist exclusively of investment-grade bonds from EU Member States, selected in accordance with predefined criteria regarding maturity, credit rating and issuer diversification. However, holders should be aware that:

- Sovereign bond values may fluctuate due to changes in interest rates, credit ratings or macroeconomic factors.
- While investment-grade bonds are considered low-risk, they are not entirely risk-free.
- The Issuer does not guarantee absolute price stability under extreme market conditions.

The reserve portfolio is composed of diversified, euro-denominated sovereign bonds issued by multiple EU Member States. No more than 20% of reserves will be allocated to any single sovereign issuer. Maturities are laddered to reduce duration risk and ensure redemption liquidity. Daily reserve valuation is performed using independent pricing sources. While the reserves are composed of low-risk instruments, they remain exposed to interest rate changes, sovereign downgrades, and macroeconomic shifts.

Pursuant to Article 34 of MiCAR, the Issuer maintains documented reserve management policies, reviewed quarterly. Interest accrued from sovereign bond holdings shall be retained by the Issuer for the sole purpose of funding operational expenses, buffer capitalization, and compliance costs, and shall not be distributed to ART holders.

9.4 Redemption & Liquidity

Holders may redeem ART tokens for euros on a T+1 basis via regulated fiat payment providers. Redemption requests are subject to liquidity availability within the pre-defined cash buffer. Under stressed market conditions, redemptions may be delayed or prorated as permitted by Article 31 (3) of the MiCAR. Redemption policies, frequency, and thresholds will be made available on the Issuer's official platform and through approved disclosures.

Redemption requests are subject to prior AML/KYC verification and jurisdictional eligibility. Redemption processing may be restricted for users located in sanctioned or high-risk jurisdictions as defined by EU AML regulation or international sanctions lists.

9.5 Legal & Regulatory compliance

The ART is issued by SIA "Waterstone Advisers", a legal entity registered in the Republic of Latvia under registration number 50203155241. The Issuer is subject to the supervision of the Bank of Latvia and complies with all applicable provisions under MiCAR. This whitepaper is submitted pursuant to Article 18 of MiCAR for regulatory approval. The ART is not legal tender, nor is it guaranteed by any public institution.

The Issuer has appointed a Compliance Officer and Money Laundering Reporting Officer (MLRO) in accordance with Latvian AML Law and Article 35 of the MiCAR. Internal audit functions are in place. The Issuer commits to ongoing reporting obligations as set forth under Articles 32 – 35 of the MiCAR, including quarterly financial reserve statements and redemption performance metrics.

9.6 No guarantee of return or profit

The ART is not designed as an investment product and does not offer any return, interest, or capital gains. Its sole purpose is to function as a digital store of value and means of payment. In case of issuer insolvency, ART holders have a pari *passu claim* on the reserve assets, and no further guarantee or compensation mechanism is provided. Asset shortfalls or adverse market events may impact redemption value.

For the avoidance of doubt, the ART does not constitute a deposit, security, or collective investment scheme. It carries no expectation of profit and does not provide any rights to the income or appreciation of underlying reserve assets.

9.7 Jurisdiction

This legal documentation and all disputes related to the ART shall be governed by the laws of the Republic of Latvia. The competent courts of Latvia shall have exclusive jurisdiction, except where EU regulations or international treaties provide otherwise. Dispute resolution may also be sought through recognized EU or national alternative dispute resolution mechanisms where applicable.

The Issuer acknowledges the cross-border supervisory powers of the European Securities and Markets Authority (ESMA) under MiCAR Title V, and (if applicable) will cooperate with competent authorities of other Member States where the ART is distributed.

Hence the Issuer hereby disclaims that:

The summary mentioned in section 13 of this white paper should be read as an introduction to the crypto-asset white paper.

Any decision of the prospective holder to purchase the asset-referenced token should be based on the content of the crypto asset white paper as a whole and not on the summary alone.

The offer to the public of the asset-referenced token does not constitute an offer or solicitation to purchase financial instruments;

Any such offer or solicitation can be made only by means of a prospectus or other offer documents pursuant to the applicable national law;

The crypto-asset white paper does not constitute a prospectus as referred to in Regulation (EU) 2017/1129 or any other offer document pursuant to Union or national law.

Tax treatment depends on the holder's circumstances; gains or losses may be subject to capital-gains or income tax. Since tax treatment of ART holdings and transactions may differ across EU Member States, prospective holders are advised to consult qualified tax professionals before acquiring Stableo.

Marketing communications are intended for informed persons; do not rely on implied returns.

Stableo is not intended for consumers in jurisdictions where crypto-assets are restricted or banned. Access may be geofenced accordingly.

Latvijas Banka, as the competent supervisory authority, retains the right to suspend, restrict, or withdraw the registration of the Issuer. In such a case, redemption, transfer or utility of the €O token may be impacted.

Appendix A: numerical stress test scenarios & methodology

A.1 Objective & Rationale

To validate the resilience of our euro-pegged stablecoin, we run systematic numerical stress tests on the reserve structure. The goal is to assess the system's ability to:

- Maintain 100% asset coverage.
- Meet large, sudden redemption waves.
- Preserve the peg under extreme macro volatility (interest rate shock, bond market liquidity shock, FX stress).

These stress tests complement regulatory requirements (e.g., MiCAR Art. 36, ESMA draft RTS on liquidity stress testing) and are integrated into our treasury governance framework.

A.2 Model Framework & Key Variables

Symbol	**Meaning**
C_0	Initial cash buffer
B_0	Initial bond portfolio (EUR)
β_t	Bond allocation vector at time t
h	Average reinvestment horizon (months)
θ	Volatility threshold triggering defensive shortening of h
ΔR	Redemption shock: outflow as % of AUM
ΔY	Parallel interest rate shift (bps)
k	Risk adjustment factor (reduces fair value of bonds by k%)
ΔL	Total liabilities at time 0
NAV_t	Net asset value after stress

A.3 Stress Scenarios

Scenario ID	Shock Type	ΔR	ΔY	Additional
S1	Redemption run	30% AUM in 24h	0 bps	
S2	Rate shock	0%	+300 bps	
S3	Liquidity + run	20% AUM	+200 bps	k=5% forced discount on bonds
S4	Combined macro	40% AUM	+500 bps	k=10%
S5	Opposite shock	-200 bps rate fall		test reinvestment risk

A.4 Calculation steps

Step 1: Compute initial NAV

$$NAV_0 = C_0 + B_0$$

Step 2: Apply redemption shock

$$C' = C_0 - \Delta R \cdot NAV_0$$

If $C' < 0$ forced bond liquidation to cover the gap.

Step 3: Apply bond repricing under rate shock. Price change approximation:

$$\Delta P \approx - D_{mod} \cdot \Delta Y$$

WhereD_{mod} is average modified duration of portfolio.

Step 5: Compute stressed NAV:

$$NAV_t = C' + B'$$

A.5 Numerical example

Assumptions

Item	Value
Initial AUM (NAV_0)	€100m
Cash buffer (C_0)	€5m
Bond portfolio (B_0)	€95m
Average modified duration	2.5

Scenario S4 (combined macro):

- ΔR = 40% -> €40m redemption
- ΔY = +500bps = +5%
- k=10%

Concluding:

- Redemption shock:
  $C' = 5m - 40m = - 35m$
  Forced sale: need to sell €35m bonds.

- Bond price drop:
  $\Delta P \approx - 2.5 \cdot 0.05 = - 12.5\%$ on bonds
  Original bond value €95m × (1 -12.5%) = €83.1m.

- Liquidity discount:
  $83.1m = 95m \times (1 - 12.5\%)$

- New NAV:
  $NAV_t = 0\ (no\ cash\ left) + 74.5m = 74.8m$

NAV drops from €100m to €74.8m, covering €60m liabilities (100m×60%) after redemption, still keeps 24.8m buffer.

- Coverage:
  $74.8m/60m = 124.6\%$

The system remains solvent.

A.6 Governance & Dynamic adjustment

If stress test shows:

- Coverage <110%: governance triggers increase of baseline buffer b_o
- Duration h is shortened
- β_t reweighted toward highly liquid bonds

Stress test results are disclosed quarterly.

A.7 Table: Stress test summary

Scenario	Redemption shock	Rate shock	Liquidity discount	Resulting NAV	Coverage vs liabilities
S1	30%	0 bps	0%	€70m	100%
S2	0%	+300bps	0%	€92.8m	100%
S3	20%	+200bps	5%	€78.3m	122%
S4	40%	+500bps	10%	€74.8m	124%
S5	0%	-200bps	0%	€104.75m	100% (gain)

A.8 Conclusion

Even under extreme combined shocks, the system maintains solvency and significant surplus above liabilities, thanks to conservative duration, baseline buffer, and dynamic rebalancing.