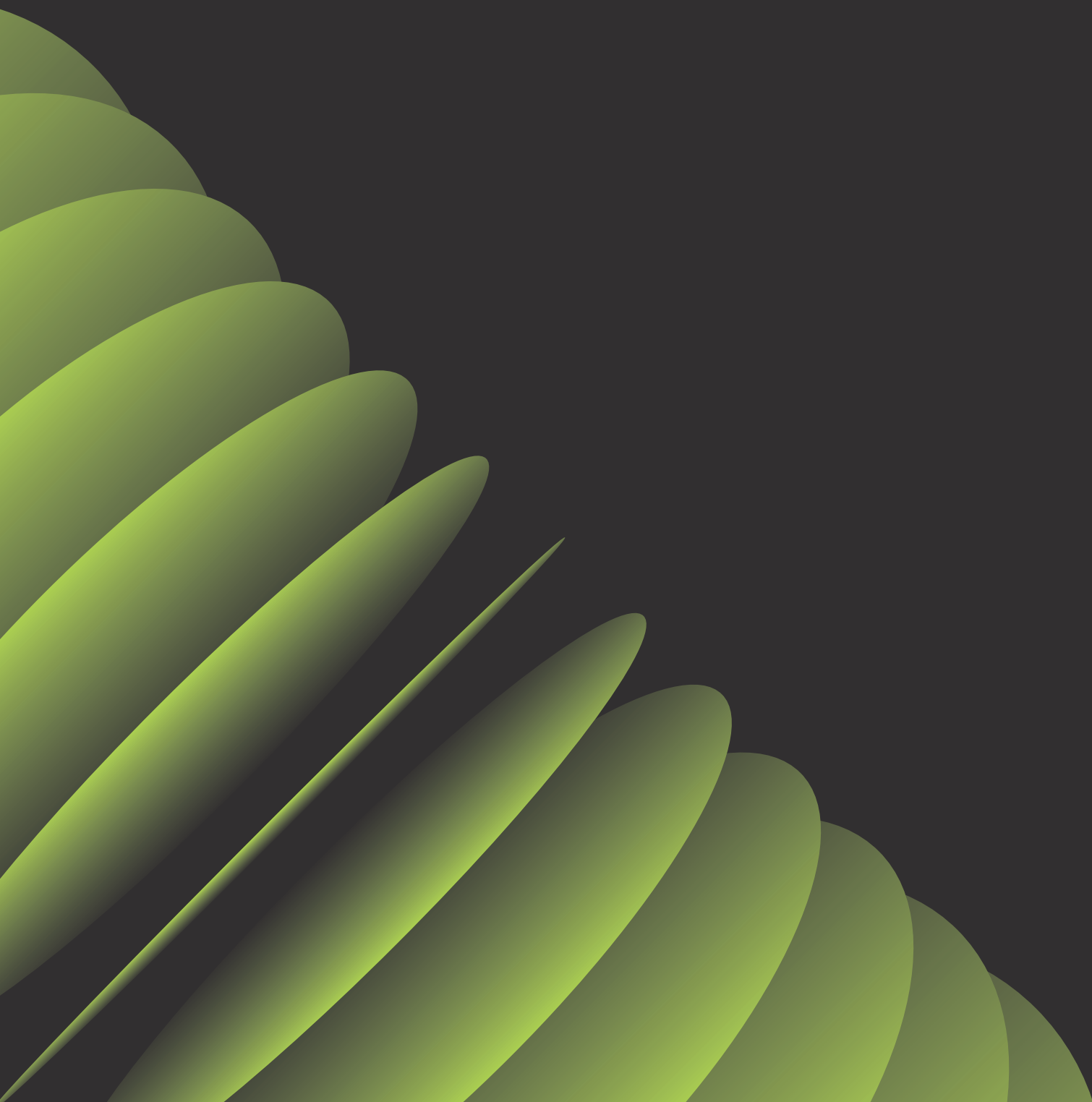




The Institutional
Guide to Ethereum
RWA Token Standards

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Ethereum Foundation and Octant.*



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The Ethereum Foundation is a non-profit organisation dedicated to supporting the Ethereum ecosystem and its long-term development.



Octant is a public goods funding platform that allocates capital to open-source and community-driven projects.

An aerial, black and white photograph of a dense urban skyline, likely New York City. The Empire State Building is prominent in the upper right. A large, semi-transparent green rectangle is overlaid on the center of the image, containing white text. The background shows a vast expanse of skyscrapers and buildings, with a body of water visible in the distance under a cloudy sky.

The standards are here. The question is which ones will define onchain finance.

Executive Summary

Asset tokenization has moved from proof-of-concept to production. Over \$30 billion in regulated securities now operate on Ethereum smart contracts, deployed by institutions including ABN AMRO, the DTCC, and Citi. The question is no longer whether blockchain works as financial infrastructure, it's which standards to build on.

This report analyzes 25+ Ethereum Improvement Proposals across seven functional categories, scoring each on a prescriptive-to-flexible spectrum to deliver neutral, evidence-based guidance.

Two standards dominate production:

ERC-3643 leads compliant securities tokenization with \$28–32B in cumulative AUM, 100+ institutional members, and confirmed regulatory engagement across the SEC, MAS, BaFin, FCA, and HKMA. In July 2025, SEC Chairman Paul Atkins became the first SEC chair to cite a token standard by name in a policy speech.

ERC-4626 dominates tokenized vaults and yield-bearing assets, with \$16B TVL across 2,700+ deployed vaults and implementations from Morpho, Ondo Finance, and Centrifuge.

All other categories show limited institutional traction. Seven years of competing securities compliance standards produced no meaningful adoption. Bond and derivative standards face barriers around oracle dependencies and regulatory uncertainty, with realistic timelines of 2027–2030. Physical asset standards remain experimental.

The practical recommendation is narrow: ERC-3643 for compliant securities, ERC-4626 for vault and treasury applications, and ERC-20/ERC-721/ERC-1155 as the foundational token layer.



Asset

Tokenization

Today

Asset tokenization is positioned to redefine global financial markets. However, the knowledge infrastructure has not kept pace.

Over \$30 billion in regulated securities now operate on Ethereum smart contracts. Bergen County, New Jersey, is digitizing \$240 billion in property records on-chain. Figure Technologies, the largest non-bank HELOC lender in the United States, has facilitated over \$16 billion in home equity originations using blockchain-based infrastructure. The question of whether asset tokenization will reshape capital markets has been answered by enterprises and institutions already operating at scale.

The challenge is not a shortage of standards, but rather a shortage of rigorous, neutral analysis helping institutional professionals understand what those standards actually do. Understanding what the architectural choices mean for compliance, security, and long-term operational commitment is an essential missing step in asset tokenization today.

Risk managers evaluating tokenized asset proposals confront an ever-expanding landscape of smart contract standards. Compliance officers discover that concepts in asset tokenization can mean radically different things depending on the standard and ecosystem. Technology

teams must distinguish between standards commanding billions in production assets and theoretical proposals that never progressed beyond draft status.

This report fills that gap. What follows is a comprehensive evaluation of the Ethereum tokenization standards landscape, analyzing the major smart contract standards using a consistent methodology, scoring them on a prescriptive-to-flexible spectrum, and assessing them against real-world adoption metrics. Detailed case studies of ERC-3643 and ERC-4626 illustrate how these standards perform in production environments.

This report is designed for risk managers scoping audits, compliance officers evaluating regulatory requirements, and technology leaders deciding which architectural commitments align with institutional constraints.

What Is Asset Tokenization?

Asset tokenization is the process of representing ownership rights to assets as digital tokens on a blockchain. These tokens are programmable, transferable, and verifiable cryptographic instruments that encode property rights, compliance rules, and economic entitlements in smart contract code.

Unlike traditional securities or property deeds, which exist as legal documents, database entries, or paper certificates, tokenized assets exist as on-chain records that combine legal ownership with programmable functionality. A tokenized bond does not just represent a claim on future cash flows. It can automatically execute coupon payments, enforce transfer restrictions based on investor qualifications, and settle transactions in minutes rather than days. This represents a fundamental shift in how assets are issued, managed, and transferred across global capital markets. This report examines how this shift is playing out in practice through in-depth case

studies of standards in production today.

The Strategic Imperative

Effective tokenization strategies balance these risk profiles by adopting robust standards, prioritizing regulatory compliance, and implementing security-first technical architectures. This report analyzes the Ethereum standards ecosystem through that lens, identifying which standards provide production-grade compliance frameworks, which remain experimental, and how institutions can navigate this landscape to capture innovation benefits while managing implementation risks appropriately.

The question isn't whether to tokenize, but how to tokenize responsibly. A core component of doing so entails the use of proven standards and comprehensive compliance frameworks that meet institutional requirements.



Patrick Hennes

Blockchain & Digital Assets Expert

“In traditional finance, infrastructure changes only when the benefits clearly outweigh the risks. Tokenization is reaching that point. The technology itself is no longer the main challenge. The real question is how institutions implement it safely. Open and well-governed standards allow innovation without forcing institutions to reinvent compliance, custody, and interoperability for every new asset.”

Balancing Innovation and Risk

The Risks of Tokenization

Tokenizing regulated financial instruments introduces measurable risk vectors.

Programmatic Risk. Smart contracts encode business logic in immutable code. Bugs, vulnerabilities, or design flaws can result in irreversible losses. Compliance-aware token standards introduce multi-layer architectures that create attack surfaces that require rigorous auditing and ongoing security maintenance.

Regulatory Risk. Blockchain-based securities occupy evolving regulatory territory. Jurisdictional questions about token classification, custody requirements, and cross-border transfer restrictions remain partially unresolved. Early adopters bear the burden of demonstrating compliance frameworks to regulators who are still evaluating the technology.

Operational Risk. Integration with existing custody infrastructure, payment systems, and reporting frameworks requires significant technical investment. Legacy systems were not designed to interface with blockchain networks, creating complexity and potential failure points during migration periods.

The Risks of Not Tokenizing

Maintaining traditional infrastructure carries its own compounding risk profile.

Obsolescence Risk. As blockchain-based settlement, custody, and compliance systems mature, institutions operating exclusively on legacy rails face mounting competitive disadvantage. The cost differential between T+2 settlement and real-time blockchain settlement grows as network effects compound around tokenized infrastructure.

Market Access Risk. Investors, asset managers, and financial institutions increasingly expect digital-native interfaces and programmable functionality. Assets that cannot integrate with emerging onchain technologies, automated compliance systems, or cross-chain settlement networks become progressively isolated from next-generation market infrastructure.

Efficiency Erosion. Manual reconciliation, multi-day settlement cycles, and fragmented compliance verification impose costs that grow in relative terms as automated alternatives scale. The cost of inaction is measured not just in absolute terms but in competitive positioning as peers adopt more efficient operating models.

Standards vs. Frameworks

The distinction between prescriptive standards and flexible frameworks has direct implications for implementation complexity, regulatory compliance, and technical risk management. Understanding where each Ethereum token standard falls on this spectrum informs critical decisions about architecture commitment, audit scope, and operational flexibility.

Defining the Terms

Prescriptive Standards mandate specific technical architectures and implementation logic. ERC-3643, for example, requires deploying ONCHAINID identity contracts (implementing ERC-734/735), maintaining an Identity Registry, configuring a Compliance contract, and establishing a Trusted Issuers Registry. This constitutes a complete multi-contract system with defined validation flows. Adopting a prescriptive standard means accepting architectural constraints in exchange for proven compliance frameworks, established security practices, and guaranteed interoperability.

Flexible Frameworks define minimal interfaces while leaving implementation details to adopters. ERC-7943, for instance, specifies two functions (`isUserAllowed()` and `isTransferAllowed()`) without prescribing how to verify users or validate transfers. This approach maximizes customization and preserves architectural control, but requires building compliance logic, identity systems, and security models internally.

The Ethereum community collectively refers to all ERCs/EIPs as "standards," though this terminology obscures an important distinction. In practice, these proposals exist on a spectrum from prescriptive standards (which mandate specific architectures) to flexible frameworks (which define minimal interfaces). For clarity, this report uses "standards" as the umbrella term when referring to ERCs and EIPs generally, while distinguishing between prescriptive and flexible approaches where precision matters.

EIP to ERC: The Ethereum Standards Process

Before examining how standards differ from frameworks, it is essential to understand how Ethereum proposals become recognized standards. An EIP (Ethereum Improvement Proposal) is the umbrella term for any proposed change or addition to the Ethereum ecosystem, from core protocol modifications to application-level standards. An ERC (Ethereum Request for Comment) is a subset of EIPs focused specifically on application-layer standards: token interfaces, smart contract patterns, and other developer-facing specifications that do not modify the core protocol itself. An ERC only becomes recognized as such after broad acceptance by the Ethereum community and progression through a formal vetting process.

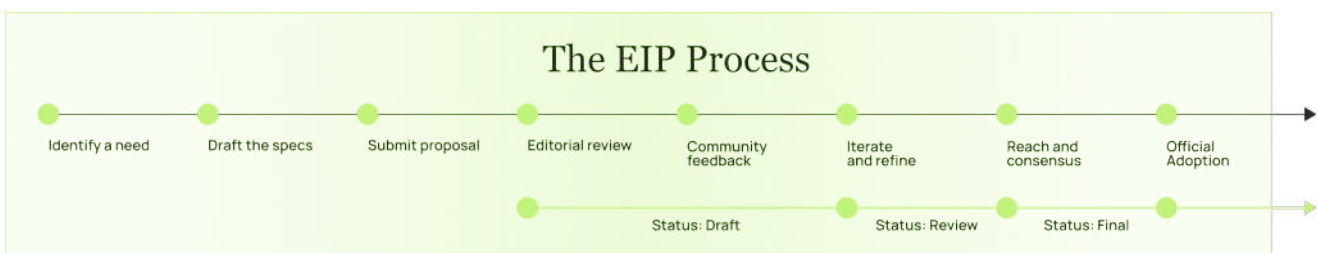
Every ERC follows a formal progression through four primary stages.

- 1. Draft.** The first formally tracked stage. An EIP is merged by an EIP Editor into the repository when properly formatted.
- 2. Review.** The author marks the EIP as ready for peer review. The proposal is fully specified

but still subject to change.

- 3. Last Call.** The final review window before moving to Final. An EIP Editor sets a review deadline, typically 14 days. If no significant changes arise, the proposal advances.
- 4. Final.** The completed standard. A Final EIP exists in a state of finality and should only be updated to correct errata or add non-normative clarifications.

This progression matters when evaluating tokenization standards. A Final status indicates completion of rigorous peer review, rough consensus, and readiness for production deployment. Draft or Review standards may be technically sound but remain unproven through the full standardization process. Throughout this report, EIP status serves as one indicator of a standard's maturity and institutional readiness, though not the only one.



Framework Labs' Analytical Methodology

To objectively classify tokenization standards along this spectrum, Framework Labs developed a five-dimensional scoring framework. Each ERC is evaluated on architectural prescription, function specificity, implementation logic, required dependencies, and ecosystem lock-in. Standards are scored 1 to 5 across each dimension, yielding a 0 to 100% position on the prescriptive-to-flexible spectrum (full methodology in Appendix A).

This analysis reveals that ERC-3643 scores 100% (maximum prescription), ERC-4626 scores 76% (highly prescriptive vault interface), while ERC-7943 and ERC-7518 score 24% (minimal frameworks). Most standards fall in the hybrid range (40 to 79%), defining interfaces without mandating complete architectures.

Throughout this report, each ERC analysis includes its position on the standard-framework spectrum. This classification helps readers understand not just what each standard does, but how much implementation flexibility remains when adopting it.



Emilie Allaert
Founder & CEO, Digital Minds

"Interoperability without compliance would be similar to innovation without a foundation. For too long, the conversation around blockchain-based financial infrastructure has been framed as a tension between openness and control, as if institutions must choose between participating in a connected ecosystem and maintaining the regulatory standards their mandates demand. That is a false choice. The tokenization frameworks that will define the next decade are those that resolve this tension by design, treating regulation not as a constraint to navigate around, but as a feature to engineer into the standard itself. When compliance logic is embedded at the token layer, governing transfer restrictions, investor qualifications, reporting obligations, and settlement finality, interoperability becomes not just possible but safe."

Standard Name	Score	Percentage	Category	Position
ERC-20/721/1155	24	96%	Foundational	Prescriptive Standard
ERC-4626	19	76%	Vaults	Prescriptive Standard
ERC-4519	18	72%	Physical Assets	Prescriptive Standard
ERC-7540	17	68%	Vaults	Hybrid
ERC-7575	15	60%	Vaults	Hybrid
ERC-5791	14	56%	Physical Assets	Hybrid
ERC-6956	13	52%	Physical Assets	Hybrid
ERC-3475	12	48%	Bonds	Hybrid
ERC-1462	12	48%	Securities	Hybrid
ERC-7092	12	48%	Bonds	Hybrid
ERC-6123	11	44%	Derivatives	Hybrid
ERC-2222	10	40%	Profit Distribution	Hybrid
ERC-1592	10	40%	Securities	Hybrid
ERC-2009	9	36%	Securities	Flexible Framework
ERC-1404	9	36%	Securities	Flexible Framework
ERC-2980	8	64%	Securities	Hybrid

ERC Standards Inter-Compared

The preceding sections established what asset tokenization is, how standards differ from frameworks, and introduced Framework Labs' analytical methodology. This section provides a comprehensive reference. Every major Ethereum tokenization standard is analyzed through a consistent framework.

The following tables organize the relevant smart contract standards into eight functional categories, evaluating each against the prescriptive-to-flexible

spectrum. Together, these tables serve as both a decision-making tool for practitioners and a landscape snapshot as it exists today.

Use Table B for strategic evaluation: Which standards should be on my radar?

Use Table C for technical assessment: What are the architectural characteristics of standards I am considering?

Standards Categories

Securities and Compliance Standards.

Standards designed to enforce regulatory requirements for tokenized securities (equity, debt, funds), incorporating features like investor whitelisting, transfer restrictions, and identity verification.

Physical Asset Standards. Standards that link blockchain tokens to physical objects through embedded chips, NFC tags, or oracle attestation, enabling authentication and ownership verification.

Vault and Treasury Standards. Standards that tokenize pools of assets (vaults), issuing shares representing proportional claims on underlying

holdings, with variations for instant settlement (DeFi) and asynchronous processing (tokenized assets).

Bond and Derivatives Standards. Standards addressing fixed-income instruments and derivative contracts, managing complex mechanics like coupon schedules, maturity dates, settlement calculations, and multi-party interactions.

Foundational Token Standards. Base-layer standards (ERC-20, ERC-721, ERC-1155) that define fundamental token types (fungible, non-fungible, multi-token) upon which all specialized standards build.

Profit Distribution and Fund Standards. Standards enabling automated distribution of dividends, interest payments, or profit allocations to tokenholders on a pro-rata basis.

Deprecated Standards. Standards that are officially stagnant, abandoned by their creators, superseded by alternatives, or failed to achieve meaningful adoption despite years of availability.

Table B: Strategic Overview of Core Components

Purpose. Evaluate standards based on strategic decision factors: what they are, their maturity level, and whether they merit consideration for a given use case. How to read this table:

- **Standard Name.** Links to official EIP documentation.
- **EIP Status.** Final (completed), Review (under evaluation), Draft (proposed), Stagnant (inactive).

- **Category.** Which of the seven functional categories above.
- **Core Purpose.** One-line description of the standard's primary function.
- **Spectrum Score.** Percentage from the prescriptive-to-flexible analysis
- **Notable Implementations.** One to three real-world examples, where available.

Table C: Strategic Technical Characteristics

Purpose. Examine the architectural properties and functional capabilities of each standard. This table answers technical questions: What compliance mechanisms exist? Can tokens be burned or forcibly transferred? What is the asset backing model? Can tokens be fractionalized? How composable is this with other systems?

Use this table when evaluating implementation feasibility, technical trade-offs, and architectural fit for specific requirements.. Each column definition can be found in the appendix.

Table B Core

Standard	EIP Status	Category	Spectrum Score
ERC-20	Final	Foundational	96%
ERC-721	Final	Foundational	96%
ERC-1155	Final	Foundational	96%
ERC-3643	Final	Securities & Compliance	100%
ERC-734	WIP	Deprecated	88%
ERC-735	Discussion	Deprecated	84%
ERC-1404	Draft	Securities & Compliance	36%
ERC-1462	Draft	Securities & Compliance	48%
ERC-1592	Draft	Securities & Compliance	40%
ERC-2009	Draft	Securities & Compliance	36%
ERC-2980	Stagnant	Securities & Compliance	32%
ERC-7943	Review	Securities & Compliance	24%

Components

Core Purpose	Notable Implementations
Fungible tokens - identical interchangeable units	USDC; DAI; LINK (thousands of implementations)
Non-fungible tokens - unique individual items	CryptoPunks; Bored Apes; ENS (millions of implementations)
Multi-token - fungible and non-fungible in one contract	OpenSea collections; gaming assets; DeFi positions
Comprehensive identity-based compliance (ONCHAINID + multi-layer validation)	Fasanara FAST (\$4.5B fund); ABN AMRO (€5M bond); Citi Token Service
Key manager (superseded by LSP6 but used in ONCHAINID)	ONCHAINID (ERC-3643 infrastructure; \$28B+ assets managed)
Claim holder (active via ONCHAINID despite Discussion status)	ONCHAINID (ERC-3643 infrastructure; production at scale)
Simple transfer restrictions with status codes	SUKU token; Harbor R-Token; multiple SEC filings
Granular checking (transfer vs transferFrom) + document management	ATLANT reference implementation only
Modular rule engine with reusable compliance logic	Mt Pelerin MPS token (first regulated tokenized share 2018)
Multi-token compliance service (centralized validation)	TokenSoft internal usage (presumed); no public deployments
Swiss law-specific compliance (superseded by ERC-3643)	None - abandoned by Tokeny in favor of ERC-3643
Lightweight universal RWA interface (DeFi-first)	None yet (proposed May 2025; 11-firm coalition backing)

Table B Core

Standard	EIP Status	Category	Spectrum Score
ERC-4519	Final	Physical Assets	72%
ERC-5791	Draft	Physical Assets	56%
ERC-6956	Draft	Physical Assets	52%
ERC-4626	Final	Vault & Treasury	76%
ERC-7540	Draft	Vault & Treasury	68%
ERC-7575	Draft	Vault & Treasury	60%
ERC-7425	Draft	Vault & Treasury	72%
ERC-3475	Draft	Bonds & Derivatives	48%
ERC-6123	Draft	Bonds & Derivatives	44%
ERC-7092	Draft	Bonds & Derivatives	48%
ERC-2222	Draft	Profit Distribution	40%
ERC-7518	Draft	Universal/Cross-Standard	24%
ERC-1400	Stagnant	Deprecated	92%
ERC-404	None	Deprecated	N/A

Components

Core Purpose	Notable Implementations
Self-authenticating assets with cryptographic chip signing (SmartNFT)	Universidad de Sevilla pilots; academic implementations
Scan-to-own via NFC/RFID chip unique identifiers	Fashion/luxury pilots (not publicly documented at scale)
Oracle-attested physical binding (no chip required)	None documented (proposed April 2023; infrastructure immature)
Tokenized vaults with instant deposit/withdrawal	Yearn Finance; sDAI (Maker); Morpho (\$1.68B+ TVL total)
Asynchronous vaults (handles RWA settlement delays)	Centrifuge pilots (private credit; treasury bonds)
Multi-asset vaults (diversified portfolios)	Centrifuge exploration; limited public implementations
Tokenized reserves (fractional reserve requirements)	Uncertain adoption; niche regulatory use cases
Abstract storage bonds (generic bond data structure)	Debond Protocol (exploratory); limited production
Smart derivative contracts (lifecycle state machine)	Academic/pilot implementations; no institutional scale
Financial bonds using traditional TradFi terminology	None documented (best positioned but early stage)
Dividend distribution tokens (automated pro-rata payments)	Maple Finance (\$1B+ loans originated; proven distribution)
Dynamic compliant interoperable security token (DyCIST cross-chain)	Zoniq (unknown scale); cross-chain RWA focus
Polymath security token (overcomplexity + off-chain dependency)	Some legacy implementations; officially stalled since 2018
Unofficial ERC-20/721 hybrid (never formal EIP)	Pandora (February 2024 hype); technical flaws led to abandonment

Table C Technica

Standard	Compliance & Permissions	Burn Functions
ERC-20	None	Varies
ERC-721	None	Varies
ERC-1155	None	Varies
ERC-3643	Built-in	Restricted
ERC-734	N/A	Yes (key revocation)
ERC-735	N/A	Yes (claim revocation)
ERC-1404	Varies	Varies
ERC-1462	Varies	Varies
ERC-1592	Varies	Varies
ERC-2009	Varies	Varies
ERC-2980	Built-in	Varies
ERC-7943	Varies	Not specified
ERC-4519	Limited	Not specified
ERC-5791	Limited	Varies

1 Characteristics

Force Transfer	Asset Backing	Divisibility	Composability
No	N/A	Fully Divisible	Open
No	N/A	Indivisible	Open
No	N/A	Semi-Fungible	Open
Yes	Direct	Fully Divisible	Limited
Indirect	N/A	N/A	Limited
No	N/A	N/A	Limited
No	Varies	Fully Divisible	Open
No	Direct	Fully Divisible	Open
No	Varies	Fully Divisible	Open
No	Varies	Fully Divisible	Open
Varies	Direct	Fully Divisible	Limited
Not specified	Varies	Fully Divisible	Open
Not specified	Direct	Indivisible	Open
No	Direct	Indivisible	Open

Table C Technica

Standard	Compliance & Permissions	Burn Functions
ERC-6956	Limited	Yes
ERC-4626	Limited	Varies
ERC-7540	Limited	Varies
ERC-7575	Limited	Varies
ERC-7425	Limited	Varies
ERC-3475	Varies	Varies
ERC-6123	Varies	Varies
ERC-7092	Built-in	Yes
ERC-2222	None	Varies
ERC-7518	Varies	Not specified
ERC-1400	Built-in	Yes
ERC-404	Varies	Yes

1 Characteristics

Force Transfer	Asset Backing	Divisibility	Composability
Indirect	Direct	Indivisible	Limited
No	Direct	Fully Divisible	Open
No	Direct	Fully Divisible	Limited
No	Direct	Fully Divisible	Limited
No	Direct	Fully Divisible	Limited
Varies	Direct	Varies	Limited
Varies	Direct	Varies	Limited
Varies	Direct	Fully Divisible	Limited
No	N/A	Fully Divisible	Open
Not specified	Varies	Varies	Open
Yes	Direct	Fully Divisible	Limited
No	None	Semi-Fungible	Restricted



Standards

in

Production

The Ethereum tokenization landscape encompasses over thirty standards, each addressing different asset classes, compliance requirements, and technical architectures. This section examines two standards through the lens of real-world production deployments. These were selected because they have accumulated the most verifiable on-chain data and institutional adoption of any tokenization standards on Ethereum today.

ERC-3643 represents the comprehensive compliance approach, with \$28 to \$32 billion in cumulative tokenized assets managed through a multi-contract architecture that prescribes identity management, compliance validation, and transfer restrictions.

ERC-4626 represents the composable interface approach, standardizing vault deposit and withdrawal mechanics while leaving asset strategy entirely to implementers.

Each case study follows the same structure, a brief overview of the standard's architecture and positioning, verifiable adoption data sourced from on-chain analytics and ecosystem reporting, and a detailed examination of a specific production deployment that illustrates how the standard operates in practice.

ERC-3643

Status	Final
--------	-------

Implementation	Prescriptive
----------------	--------------

Total Assets Tokenized	\$28-32B
------------------------	----------

Members	+140
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“ERC-3643 was designed with a long-term vision: if blockchain is to become the infrastructure for financial markets, regulated assets must remain interoperable with the broader ecosystem. By building on ERC-20 while enforcing compliance fully on-chain, we created a system where every valid transfer becomes a regulatory checkpoint, turning the blockchain into a trusted registry for securities.”



Joachim Lebrun

Author of ERC-3643 & Head
of Blockchain at Apex Group

The Standard at Glance

ERC-3643 originated as Tokeny's T-REX protocol in 2017, addressing a gap that ERC-20 left open: no mechanism for enforcing regulatory compliance at the token layer. After four years of production refinement across hundreds of deployments, Tokeny submitted the architecture to Ethereum's standardization process in July 2021. On December 15, 2023, it became the first token standard designed explicitly for compliant asset tokenization to achieve Final status.

The standard implements a multi-layer compliance framework through coordinated smart contracts. At the foundation sits ONCHAINID, a decentralized identity system implementing ERC-734 (Key Manager) and ERC-735 (Claim Holder). ONCHAINID enables investors to prove compliance credentials without exposing sensitive data on-chain. Above this identity layer, four contracts orchestrate validation: the Identity Registry maps wallet addresses to verified identities, the Trusted Issuers Registry defines which entities can issue valid claims, the Claim Topics Registry specifies required credentials, and the Compliance contract enforces token-specific transfer rules.

When a transfer is initiated, the system validates that both parties have valid ONCHAINIDs with appropriate claims from trusted issuers, confirms that the transfer satisfies all compliance rules, and executes the transaction only if all conditions are met. This architecture scores 100% on the prescriptive-to-flexible spectrum because it mandates complete implementation patterns. Adopters must deploy the full contract suite and integrate with ONCHAINID infrastructure. The trade-off is deliberate: comprehensive architectural prescription in exchange for proven, auditable regulatory compliance that operates independently of any single platform.

Adoption Data

Total Assets Tokenized

\$28 to \$32 billion in cumulative real-world assets tokenized using ERC-3643. This range represents consensus across multiple independent sources. The ERC-3643 Association cited \$32B+ in its ISO standardization initiative filing. Kadena's RWA tokenization report (July 2025) corroborated the \$32B+ figure. The QualitaX case study references \$30B+.

Important caveat

These are cumulative issuance figures, self-reported by the ERC-3643 ecosystem. The Dune Analytics dashboard tracks on-chain deployment activity (token contracts, whitelisted investors, transactions) but does not independently calculate dollar-denominated AUM by multiplying on-chain supply by price. The \$28 to \$32B range reflects consensus across multiple independent sources citing the Association's data, not the current outstanding NAV.



Dennis O'Connell
President ERC3643 Association

“ERC-3643 has fully entered its stride. We’re the most institutional compatible technology which has been validated by 140 institutional members including the largest Fund Admins, Investment Banks, and FMI’s, \$35B on public/private chains, 23 regulatory jurisdictions for use in private securities, engagement with the SEC and the US government on variety of levels. These aren’t organizations that move fast or take risks lightly. The fact that they’re here tells you that compliant tokenization for securities isn’t a future conversation anymore — it’s happening now, and institutions want to be part of shaping it while ensuring the right protections and law.”

Regulatory Engagement

The Association has engaged with 21+ regulators and NGOs globally, with ERC-3643-based securities approved in 11+ jurisdictions.

The SEC engagement is particularly notable. On July 31, 2025, SEC Chairman Paul S. Atkins referenced restricting tokenized securities to standards with built-in compliance features, naming ERC-3643 specifically. This marked the first time the SEC cited a specific token standard in a policy speech.

SEC 
United States
Confirmed
Crypto Task Force meeting, July 16, 2025. Chairman Atkins cited ERC-3643 by name in policy speech, July 31, 2025.

BaFin 
Germany
Confirmed
Source: Association's press release, October 2024

ESMA 
EU
Confirmed
Referenced in DLT Pilot Regime report published in September 2022

HKMA 
Hong Kong
Confirmed
Referenced in SEC meeting materials, July 2025.

MAS 
Singapore
Confirmed
Source: Association's press release, October 2024

FCA/HM 
UK
Confirmed
Referenced in SEC meeting materials, July 2025.

DFSA 
Dubai
Confirmed
Source: Association's press release, October 2024

CSSF 
Luxembourg
Confirmed
Source: Association's press release, October 2024

FINMA 
Switzerland
Not Confirmed
Swiss members present in Association, but direct engagement not publicly disclosed.

Industry Vertical Breakdown

The Dune dashboard includes an industry categorization of deployed ERC-3643 tokens, enriched by QualitaX through qualitative research with stakeholders. This provides a deployment count breakdown (number of T-REX Factory token contracts per vertical), not a dollar-weighted breakdown.

Asset Type

Implementation

Securities / Equity

Multiple issuers via T-REX Factory

Funds (MMF, PE, VC)

Fasanara FAST token, Apex Group fund tokenization, 3iQ Corp

Bonds (Corporate, Green)

ABN AMRO €5M green bond, others

Real Estate

BlocHome, Cyndicate Club, T-RIZE Group

Other

Diamond Standard Fund Token (commodities), Penomo (renewable energy)

Case Study

In September 2023, ABN AMRO became the first Dutch bank to register a digital green bond on a public blockchain. The bank issued a €5 million (\$5.3M) green bond on Polygon using ERC-3643, structured through Tokeny's tokenization platform. The proceeds were used by Vesteda, a Dutch residential real estate investment manager, to refinance green assets under Vesteda's Green Finance Framework. DekaBank, a major German institutional asset manager, served as the sole investor, receiving tokens representing its €5 million position. Fireblocks provided key management and wallet infrastructure for DekaBank's custody of the digital bond.

The deployment illustrates how ERC-3643's architecture operates at each layer of a regulated securities transaction. ABN AMRO acted as the trusted claim issuer within the ONCHAINID framework. Using Tokeny's platform, the bank collected KYC/KYB data off-chain through its existing compliance processes. Once verified, ABN AMRO issued a cryptographic claim to DekaBank's identity contract (ONCHAINID) confirming regulatory eligibility, without sharing any underlying personal data on-chain. This approach satisfied both Dutch securities law and

GDPR privacy requirements through a single mechanism: the on-chain record contains only the attestation that verification occurred, not the verification data itself.

At the token level, the ERC-3643 smart contract enforced transfer restrictions automatically. The bond could only be held by investors with valid ONCHAINIDs containing verified claims from ABN AMRO as the designated trusted issuer. Every attempted transfer triggered an on-chain compliance check against the Identity Registry and Compliance contract before execution. ABN AMRO retained the ability to track token ownership, freeze tokens if regulatory circumstances changed, and recover digital securities to alternative wallets if an investor's keys were lost. Token recovery is one way to address institutional objections to blockchain deployments, as ONCHAINID links identity to a contract rather than a single wallet address. This configuration means tokens can be reassigned to a new wallet associated with the same verified identity without disrupting the on-chain ownership registry.

The modular compliance layer also enabled ABN AMRO to configure offering-specific rules without

The modular compliance layer also enabled ABN AMRO to configure offering-specific rules without custom smart contract development. Tokeny's platform provides pre-built compliance modules for country restrictions, investor holding limits, monthly transfer caps, and supply management. These modules, developed through hundreds of prior client implementations, allowed ABN AMRO

to define the bond's compliance parameters through configuration rather than code. The standard's proxy-based upgradeability further ensured that if regulations changed or security patches became necessary, the token logic could be updated without migrating the bond to a new contract address or disrupting existing investor positions.

For institutional readers evaluating ERC-3643, the ABN AMRO deployment demonstrates three points.

First, a regulated bank with existing compliance infrastructure was able to extend its processes onto a public blockchain rather than replace them. ABN AMRO's compliance team continued performing KYC through established procedures, with the blockchain layer adding automated enforcement rather than introducing unfamiliar workflows.

Second, the bond operated on Polygon's permissionless network while maintaining the transfer controls that securities regulation requires. The ERC-3643 smart contracts created a permissioned environment within the public chain, restricting participation to verified investors without requiring a private or permissioned blockchain.

Third, the architecture continued to function independently of Tokeny's platform. As Tokeny's own case study documentation notes, if the platform encountered issues, compliance enforcement and the on-chain registry would remain fully operational and auditable, as both are encoded in the smart contracts themselves rather than dependent on off-chain infrastructure.

ERC-4626

Status	Final
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Implementation	Prescriptive
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TVL	\$16B
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Members	+105
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The Standard at Glance

ERC-4626 emerged from a composability crisis in DeFi. By 2021, dozens of yield-generating vault protocols had launched with functionally similar concepts but incompatible interfaces. Aggregators building on these vaults faced an integration nightmare, writing thousands of lines of protocol-specific adapter code for what should have been standardized operations. Joey Santoro, founder of Fei Protocol, recognized that this fragmentation was throttling DeFi composability and proposed a universal interface for tokenized vaults in December 2021. Co-authored with transmissions11 (t11s), Jet Jadeja, and Joey Santoro, among others, the proposal moved rapidly through Ethereum's standardization process and achieved Final status on March 18, 2022.

The standard defines a minimal but complete interface for tokenized vaults, extending ERC-20 with eight core functions: `deposit()` and `mint()` for adding assets and receiving shares, `withdraw()` and `redeem()` for burning shares and retrieving assets, preview functions for calculating expected outcomes, and view functions exposing the vault's underlying asset and total holdings. This interface scores 76% on

the prescriptive-to-flexible spectrum because it standardizes function signatures and expected behaviors while leaving strategy implementation entirely to vault creators. A vault might pursue yield through lending, liquidity provision, staking, or any other approach. The standard remains agnostic towards yield generation, only ensuring that the deposit, withdrawal, and accounting interfaces remain consistent.

This architectural contrast with ERC-3643 is instructive. Where ERC-3643 mandates a complete compliance infrastructure deployed as a coordinated system, ERC-4626 provides interface standards and trusts implementers to handle internal logic. A pure DeFi vault needs no identity system, no claims verification, no multi-signature governance. It needs an asset management strategy and correct share accounting. This simplicity enabled hundreds of implementations within months of finalization. More importantly, it created network effects: each new ERC-4626 vault became immediately compatible with every aggregator, router, and wallet that had already integrated the standard.

Adoption Data

ERC-4626 is fundamentally different from permissioned token standards in how adoption is measured. The standard's adoption is measured by protocol implementation, on-chain vault deployments, and total value locked across independently operated vaults. Primary data sources include the Tokenized Vault Leaderboard, the Web3 Ethereum DeFi open-source scanner, Kiln Research ("The Rise of Curated DeFi Vaults," July 2025), DefiLlama, and Dune Analytics.

Total Value Locked

ERC-4626 TVL is on-chain verifiable. Each vault's `totalAssets()` function returns its current value, denominated in the underlying token.

Multiple data sources converge on the following range: \$16 billion+ on Ethereum alone, across 2,700+ deployed vaults. (ainvest.com, December 2025)

\$4.4 billion in curated DeFi vault TVL specifically

(June 2025), growing 28x from under \$150 million in June 2024. (Kiln Research via Techopedia, July 2025) ~\$5 billion in Morpho protocol deposits alone across its ERC-4626 curated vaults. (Kiln Research via Techopedia, July 2025)

50+ vault deployments per week consistently since the standard's introduction. (Kiln Research via Techopedia, citing Dune Analytics)

Important caveats: The \$16B Ethereum-only figure includes all vault types (DeFi yield, staking, RWA). Not all of this is "RWA" in the traditional sense. Double-counting risk exists where vaults wrap other vaults or deposit into lending protocols that themselves use ERC-4626. The line between an "ERC-4626 implementation" and a "protocol that wraps ERC-4626" is blurry.



Corn
BD at Yearn

"Yearn co-wrote ERC-4626 because the market needed a standard for tokenized vaults. Before ERC-4626, every new yield source required a custom adapter, new code, and another audit — which added complexity and risk. With ERC-4626, integrations are standardized, letting us bring strategies to market faster, more safely, and with far less overhead"

Ecosystem Adoption

The standard is represented by the Tokenized Vault Foundation, which evolved from the earlier ERC-4626 Alliance to steward the standard alongside its extensions (ERC-7540 and ERC-7575).

The Foundation's membership includes Yearn, Euler, Balancer, Ethena, Gearbox, and other major DeFi protocols. Adoption beyond the Foundation remains

organic, driven by open-source reference implementations from OpenZeppelin and Solmate, and by the practical reality that building a vault with a non-standard interface now means excluding it from the broader DeFi ecosystem.

The "ecosystem" is measured by protocol adoption, implementation libraries, and developer tooling.

Category

Notable Protocols

Lending / Curated Vaults

Morpho (~\$5B deposits), Euler V2, Maple Finance, Gearbox, Silo V2

Yield Aggregation

Yearn Finance V3 (first major adopter, April 2022), Sommelier

RWA / Treasuries

Ondo Finance (USDY/OUSG, \$1.6B+ AUM), Centrifuge (ERC-4626 + ERC-7540, JAAA fund \$650M+)

RWA / Private Credit

Apollo via Morpho (ACRED vault), Maple Finance

Vault Curation / Risk

Gauntlet, Steakhouse Financial, MEV Capital

Public Goods Funding

Octant V2 (yield-donating ERC-4626 vaults, Golem Foundation)

Regulatory Surface Area

ERC-4626 has no standard-level regulatory engagement. There is comparatively little engagement with regulators. However, the standard's regulatory surface area is significant and growing through two channels.

First, individual protocols built on ERC-4626 have direct regulatory engagement. Ondo Finance met with the SEC Crypto Task Force in April 2025 to discuss compliant on-chain securities issuance. BlackRock's BUIDL (\$2.9B+ AUM) operates as an SEC-registered investment vehicle using vault infrastructure. Superstate runs an SEC-registered Short-Term Government Bond Fund with on-chain shares.

Second, ERC-4626 vaults have been analyzed under MiCA (Markets in Crypto-Assets Regulation) by the Blockchain Center for Applied Studies, examining how vault shares may be classified under MiCA's token taxonomy. Kiln researchers assessed that because vaults allow users to retain direct custody, many traditional intermediary rules may apply only at the fiat layer rather than inside the vault itself.

The most accurate framing for this report: ERC-4626 provides the technical infrastructure that regulated products are built on, while compliance is handled at the protocol or product layer. In regulated environments, ERC-4626 is often paired with ERC-3643 for investor eligibility gating or with other compliance standards for identity verification.

Regulatory relevance comes through protocols that are building on ERC-4626:

Ondo Finance

In-Person Crypto Task Force meeting at the SEC (US) in April 2025)

BlackRock BUIDL

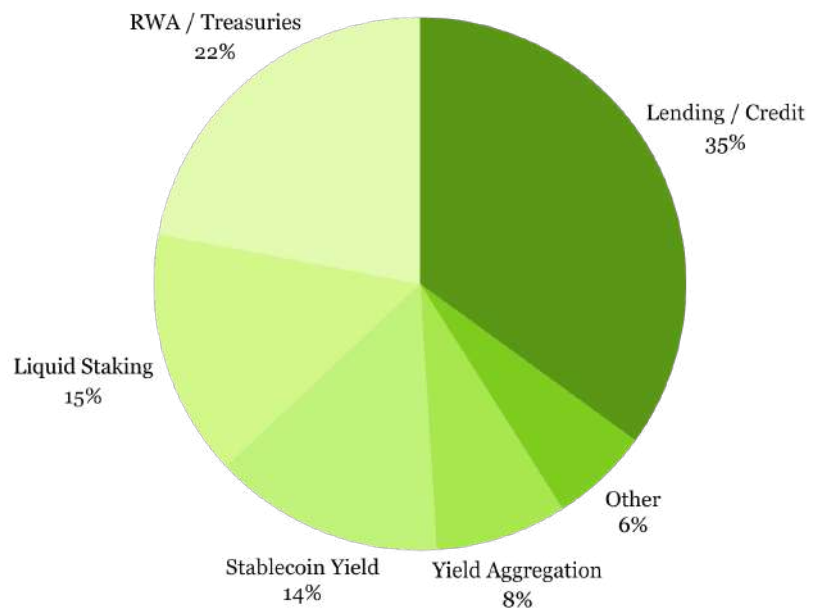
SEC-registered (US) investment-vehicle. \$2.9B+ AUM.

Superstate

SEC-registered (US) short-term government bond fund.

Industry Vertical Breakdown

ERC-4626 spans DeFi and RWA use cases. Unlike ERC-3643 (where QualitaX manually enriched industry data from the Dune dashboard), ERC-4626 vertical classification must be derived from protocol-level categorization. For additional RWA context: tokenized U.S. Treasuries reached \$7.5 billion by June 2025, up from \$100 million in January 2023. BlackRock's BUIDL dominates that segment with 40% market share (\$2.9B+ AUM). On-chain private credit reached \$16.8 billion, with Apollo and Maple deploying credit vaults using ERC-4626 infrastructure.



Vikram Arun
Co-Founder Superform

"Superform has been building on top of ERC-4626 since inception and engaged with the Crypto Task Force in February 2026. They are well-versed in vault products and I strongly believe they want to see entirely non-custodial, decentralized crypto take off in the U.S."

"These might be high bars to meet unanimously, and as an industry we need to make it easier for consumers to understand vaults with standardized disclosures, transparency, and as a pure software interface."

Extensions

The standard has also spawned extension standards for use cases that require capabilities beyond ERC-4626's atomic settlement model:

ERC-7540 for asynchronous deposit/redemption for RWA vaults.

ERC-7575 for multi-asset vault extension.

"We created ERC-7540 and ERC-7575 to extend ERC-4626 vaults for advanced DeFi use cases. Both standards address limitations in the original tokenized vault specification to better support real-world assets and multi-asset scenarios."



Jeroen Offerijns
CTO at Centrifuge Labs

Case Study

Octant is a funding platform launched on the Ethereum mainnet in August 2023. Through its first eleven funding epochs on v1, Octant distributed over \$18 million in grants to impactful Ethereum ecosystem and open-source projects, funded by staking yield from 100,000 ETH staked by the Golem Foundation. In late 2025, Octant began migrating to v2, a fundamental architectural upgrade that replaces the rigid 90-day epoch model with composable DeFi infrastructure. At the center of that infrastructure sits ERC-4626.

Octant's Funding Vaults are ERC-4626-compliant smart contracts that deploy capital into DeFi yield strategies and route the generated yield to fund ecosystem growth. The architecture separates principal management from yield routing. When a capital provider deposits assets (for example, USDC) into an Octant Funding Vault, the vault issues standard ERC-4626 shares representing the depositor's principal. The vault then allocates those assets across configurable DeFi strategies, which can include Aave, Lido, Morpho, or Sky Compounder among others.

The key innovation is what Octant calls the Yield Donating Strategy. When a strategy generates profit, the system mints new shares representing the yield

and sends them not back to the depositor to one or multiple designated receiving addresses. This donation address can be a Payment Splitter that distributes funds to multiple recipients, or it can route through allocation mechanisms such as quadratic funding, quadratic voting, or other customizable funding rounds. The depositor's principal remains intact with only the yield being redirected.

This matters for ERC-4626 because Octant's architecture demonstrates the standard's flexibility beyond its original DeFi yield optimization context. The entire system is built on a Solidity port of Yearn V3's vault architecture with additional security audits, and it supports Safe multisig treasuries for institutional-grade governance.

For institutional readers evaluating ERC-4626, the Octant deployment illustrates several points about the standard's adaptability.

First, ERC-4626 is not limited to DeFi yield optimization. Octant repurposes the vault standard as infrastructure for sustainable funding, a use case the standard's original authors did not design for but that the interface accommodates without modification. The same `deposit()`, `withdraw()`, `totalAssets()`, and share accounting functions that power lending vaults and yield aggregators also power a regenerative funding network.

Second, the multi-tiered vault architecture shows how ERC-4626's composability operates in practice. Each sub-strategy is itself an ERC-4626 vault. The parent multi-strategy vault is also an ERC-4626 vault. Aggregators, wallets, and other DeFi primitives can interact with any layer of this stack through the same interface, without needing to understand the yield-donation logic underneath.

Third, the transition from v1 to v2 illustrates why standardization matters for longevity. Octant v1 used a custom architecture tied to 90-day epochs and GLM token locking. v2's migration to ERC-4626 vaults opens the system to any ERC-20 asset, any DeFi strategy, and any capital provider, because the vault interface is the same one the rest of the ecosystem already speaks.



Foundational

Token

Standards

Having examined two production case studies in the previous chapter, illustrating how ERC-3643's compliance system and ERC-4626's vault architecture operate at scale, we now turn to the foundational building blocks these specialized standards extend. Every tokenization approach, regardless of complexity or regulatory requirements, ultimately builds upon three core token primitives that define how digital assets behave on Ethereum: fungible tokens that represent identical units, non-fungible tokens that represent unique items, and hybrid multi-token contracts that manage both simultaneously.

These foundational standards represent the technical bedrock that enables everything from simple utility tokens to sophisticated securities. ERC-20 established the template for fungible assets in 2015 and remains the most widely adopted token standard in blockchain. ERC-721 pioneered non-fungible tokens in 2018, enabling unique digital and physical asset representation. ERC-1155 introduced multi-token contracts in 2019, allowing single contracts to manage multiple asset types with dramatically improved gas efficiency. Understanding these foundations clarifies why specialized standards make specific architectural choices. ERC-3643 extends ERC-20 for fungible securities. Physical asset standards leverage ERC-721 for unique items. Structured products explore ERC-1155 for complex fund structures.

The order matters here. We examined specialized solutions first to establish why tokenization requires more than simple token transfers. Compliance, identity, recovery, and institutional requirements drive architectural complexity. Now we step back to the simpler foundations, understanding what these specialized standards inherit, extend, and occasionally need to work around. Every question about why ERC-3643 works the way it does traces back to ERC-20's design decisions. Every physical asset standard's NFT approach builds on ERC-721's template. Every vault or fund structure's token economics reflects choices these foundational standards make possible.

ERC-20: Fungible Token

Intro

ERC-20 defines the standard interface for fungible tokens: digital assets where every unit is identical and interchangeable, just like traditional currency or stock shares. Created by Fabian Vogelsteller and Vitalik Buterin in 2015, ERC-20 established the template that made Ethereum the dominant platform for token issuance. The standard specifies six mandatory functions (transfer, transferFrom, approve, balanceOf, totalSupply, allowance) and two events that any fungible token must implement, creating universal compatibility across wallets, exchanges, and DeFi protocols.

Key Features

- **Universal compatibility.** Every ERC-20 token works with any wallet, exchange, or DeFi protocol supporting the standard. No custom integration required.
- **Allowance mechanism.** The approve and transferFrom pattern enables delegated transfers, powering DEXs, lending protocols, and automated trading strategies.
- **Divisibility.** Supports up to 18 decimal places (configurable), enabling fractional ownership and precise value representation.
- **Simplicity.** Minimal interface keeps implementation straightforward while enabling sophisticated applications through composition.

Status	Final
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Prescriptive Spectrum	96% (highly standardized interface with minimal flexibility)
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Adoption	Ubiquitous (hundreds of thousands of tokens, trillions in transaction volume)
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Best For	Identical, interchangeable units (currencies, shares, utility tokens)
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Current Status

ERC-20 achieved Final status in 2017 and remains the most widely adopted token standard in blockchain. Hundreds of thousands of ERC-20 tokens exist with trillions of dollars in cumulative transaction volume. The standard's ubiquity creates powerful network effects. Wallets universally support it, exchanges list it by default, and every DeFi protocol integrates it. All specialized tokenization standards either extend ERC-20 (securities, vaults) or deliberately choose alternatives (ERC-721 for unique assets) based on specific requirements. The standard's longevity demonstrates that simplicity, clear specifications, and solving real problems drive adoption more effectively than technical sophistication.

When to Use

Use ERC-20 for any asset where units are fungible and interchangeable: currencies, stablecoins, utility tokens, governance tokens, or security tokens representing fungible ownership stakes. The standard works for both DeFi-native assets (wrapped ETH, protocol governance tokens) and tokenized real-world assets, where identical units share the same rights and characteristics.

When NOT to Use

Avoid ERC-20 for unique assets where individual items have distinct characteristics or values: physical artwork, real estate parcels, collectibles, or any item where ownership history or individual attributes matter. ERC-20's fungibility assumption breaks down when units are not interchangeable. Also, insufficient alone for regulated assets requiring compliance verification, identity management, or transfer restrictions.

ERC-721: Non-Fungible

Intro

ERC-721 defines the standard interface for non-fungible tokens: digital assets in which each token is unique. Created by William Entriken, Dieter Shirley, Jacob Evans, and Nastassia Sachs in 2018, ERC-721 established the technical foundation for NFTs by specifying how to create, track, and transfer unique tokens with individual identifiers and metadata. Unlike ERC-20's fungible units, each ERC-721 token has a unique tokenId that distinguishes it from all others, enabling representation of one-of-a-kind items ranging from digital artwork to tokenized real estate parcels to physical asset provenance tracking.

Key Features

- **Unique identification.** Every token has a distinct tokenId enabling individual tracking, ownership history, and metadata association for each item.
- **Metadata extensibility.** Optional tokenURI() function links to off-chain metadata (images, descriptions, attributes) while maintaining on-chain ownership records.
- **Indivisibility.** Tokens represent whole units only. You own token #1234 completely or not at all. No fractional ownership without additional mechanisms.
- **Composability.** Standard transfer and approval functions enable marketplace integration, lending protocols, and derivatives while maintaining uniqueness.

Status	Final
Prescriptive Spectrum	96% (standardized core interface with optional extensions)
Adoption	Ubiquitous (millions of NFT collections, billions in transaction volume)
Best For	Unique, individually distinct assets (art, collectibles, real estate, identity documents)

Current Status

ERC-721 achieved Final status in January 2018 and became synonymous with the NFT wave of 2021-2022. Millions of NFT collections exist across art, gaming, virtual worlds, and collectibles. While NFT market cycles have moderated, the standard's technical foundation remains solid and widely adopted. For asset tokenization, ERC-721 provides the logical choice for unique physical assets, real estate, and items where provenance and individual characteristics matter. The standard's maturity, universal wallet support, and marketplace infrastructure make it the default for non-fungible asset representation.

When to Use

Use ERC-721 for tokenizing unique assets where individual characteristics, provenance, or ownership history matter. Physical assets like real estate parcels, luxury goods, or artwork fit naturally since no two properties or pieces are identical. Digital collectibles, gaming items with unique attributes, event tickets with specific seats, and identity documents all benefit from non-fungibility. Many physical asset tokenization standards (ERC-4519, ERC-5791, ERC-6956) build on ERC-721 precisely because physical items typically have individual characteristics even within product categories. Each sneaker, watch, or gold bar is distinct.

When NOT to Use

Avoid ERC-721 when assets are truly fungible and interchangeable: currency, most securities, utility tokens, or any scenario where one unit equals any other unit. The per-token uniqueness creates unnecessary complexity and gas inefficiency when fungibility suffices. Also problematic for fractional ownership without additional infrastructure. If 100 people own shares in a property, ERC-721 alone cannot represent proportional claims. Consider ERC-1155 instead for scenarios requiring both fungible and non-fungible tokens in a single contract, or stick with ERC-20 when fungibility is the dominant characteristic.

ERC-1155: Multi-Token

Intro

ERC-1155 defines a multi-token standard enabling single contracts to manage unlimited token types, mixing fungible and non-fungible tokens with dramatically improved gas efficiency through batch operations. Created by Witek Radomski of Enjin in 2019, ERC-1155 emerged from gaming use cases where players need both fungible currencies and unique items managed together. The standard introduces the concept of token IDs representing types rather than individual tokens. ID 1 might represent 1,000 fungible gold coins while ID 2 represents a unique legendary sword, all within one contract.

Key Features

- **Token type flexibility.** Single contract manages both fungible tokens (multiple units per ID) and non-fungible tokens (single unit per ID) simultaneously through a unified interface.
- **Batch operations.** Transfer multiple token types in a single transaction, dramatically reducing gas costs for portfolio transfers or multi-asset trades.
- **Efficient storage.** Optimized contract design reduces deployment and operational costs compared to deploying separate ERC-20 and ERC-721 contracts for each asset type.
- **Metadata flexibility.** The optional URI system supports both token-type-level metadata and individual token metadata, accommodating various asset structures.

Status

Final

Prescriptive Spectrum

96% (standardized interface with flexible token type management)

Adoption

High (gaming, DeFi positions, emerging institutional use)

Best For

Managing multiple token types (fungible + non-fungible) in single contracts

Current Status

ERC-1155 achieved Final status and gained significant adoption in gaming (Enjin, Immutable), DeFi (representing LP positions), and NFT platforms (OpenSea supports it natively). For asset tokenization, adoption remains emerging but promising. Multi-asset vaults, structured products, and fund structures with multiple share classes represent natural fits. The standard's gas efficiency advantages become more compelling as transaction costs rise and portfolio complexity increases. The technical foundation is solid. Market discovery of optimal institutional use cases continues.

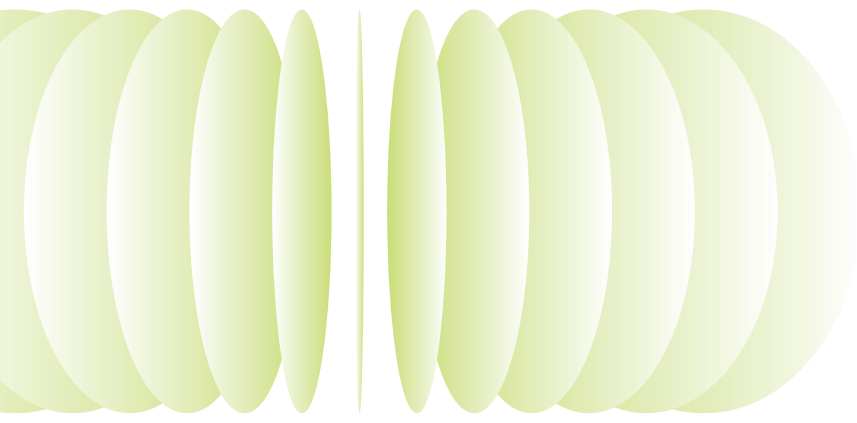
When to Use

Use ERC-1155 for managing related asset collections requiring both fungible and non-fungible characteristics: gaming ecosystems with currencies and items, multi-class fund structures with different share types, or asset portfolios bundling multiple securities. Particularly valuable when batch operations matter, such as transferring entire portfolios, managing complex fund structures, or scenarios where gas efficiency from bundled operations justifies single-contract architecture. Emerging applications include structured products with multiple tranches, diversified

portfolios managed as single units, and asset-backed securities with fungible shares and unique collateral tracking.

When NOT to Use

Avoid ERC-1155 when simplicity matters more than flexibility. Single-token-type projects gain nothing from multi-token capability and face increased complexity. ERC-20 remains preferable for purely fungible assets where universal compatibility and maximum simplicity drive adoption. ERC-721 works better for exclusively non-fungible collections where per-token uniqueness dominates. The standard's power comes from managing multiple types together. Forcing it onto single-type scenarios adds unnecessary abstraction. Also consider that wallet and infrastructure support, while growing, remains less universal than ERC-20 or ERC-721, potentially creating user experience friction.



The Asset Tokenization Connection

Every specialized tokenized asset standard builds on these foundations. ERC-3643 extends ERC-20 because securities are fungible. Physical asset standards (ERC-4519, ERC-5791, ERC-6956) leverage ERC-721 because physical items are unique. Vault standards (ERC-4626 and extensions) operate on ERC-20 shares representing fungible claims. Future structured products may increasingly adopt ERC-1155 for complex fund structures requiring multiple share classes or asset types within unified management.

The prescriptive spectrum scores reflect this: foundational standards score 96% because they define core behavior with minimal flexibility, creating the interoperability that makes Ethereum's token ecosystem possible. Specialized standards add compliance, identity, and institutional requirements on top of these proven foundations, extending rather than replacing the building blocks that make tokenization work.

Choosing Your Foundation

Choose ERC-20 when: Assets are genuinely fungible (identical units). Maximum composability with DeFi is required. Simplicity and universal compatibility are paramount. Use cases: Securities, stablecoins, governance tokens, fungible assets.

Choose ERC-721 when: Each asset is unique and distinct. Ownership provenance matters. Metadata varies per individual token. Use cases: Real estate, physical assets, unique collectibles, identity documents.

Choose ERC-1155 when: Managing multiple related token types. Batch operations provide meaningful gas savings. Both fungible and non-fungible tokens are needed in one contract. Use cases: Gaming economies, multi-asset



Securities

&

Compliance

Standards

This section explores the alternative standards that attempted different trade-offs along the prescriptive-flexible spectrum. Five standards from 2018 to 2020 represent the early evolutionary path of securities tokenization thinking, each proposing distinct architectures ranging from granular multi-function checking (ERC-1462) to minimalist two-function interfaces (ERC-1404) to entirely externalized rule engines (ERC-1592). Two newer entrants arrived in 2023 and 2025 respectively. ERC-7518 extends ERC-1155 with partitioned, semi-fungible security tokens and cross-chain compliance. ERC-7943 takes a minimal universal interface approach backed by an 11-firm coalition.

The prescriptive spectrum becomes particularly visible across these standards. ERC-1462 scores 48% through its four-function validation pattern and document management, providing more structure than simple interfaces while remaining implementation-flexible. ERC-1592 achieves 40% by externalizing compliance into modular rule contracts, enabling sophisticated composition at the cost of architectural complexity. ERC-1404 and ERC-2009 both score 36%, representing opposite approaches to minimalism. ERC-1404 achieves this through inline restriction checking, while ERC-2009 takes a multi-token service pattern approach. ERC-2980 sits at 32% as a jurisdictionally focused framework that prescribed Swiss compliance outcomes without mandating implementation mechanisms, ultimately abandoned by its own creators. ERC-7518 and ERC-7943 both score 24%, though they differ significantly in scope. ERC-7518 extends ERC-1155 with partitioned token management and cross-chain compliance infrastructure, while ERC-7943 defines a minimal interface with enforcement actions designed to work across multiple token types.

Among the 2018-2020 generation, none achieved meaningful institutional adoption. ERC-1404 secured regulatory validation through SEC filings and demonstrated production viability, but remained confined to simpler use cases. ERC-1592 proved its modular rule engine concept with Mt Pelerin's MPS token, yet gained no broader ecosystem traction. ERC-1462, ERC-2009, and ERC-2980 effectively failed to launch beyond theoretical proposals.

ERC-1462: Base Security

ERC-1462 defines a base security token standard with four distinct compliance checking functions and on-chain document management capabilities. Proposed by ATLANT in October 2018 as the first merged standard addressing general security token utilization, ERC-1462 distinguished itself through granular validation. It separates `checkTransferAllowed()` from `checkTransferFromAllowed()` to enable different rules for direct versus delegated transfers, plus dedicated `checkMintAllowed()` and `checkBurnAllowed()` functions for lifecycle control. The standard couples compliance checking with document attachment capabilities, enabling tokens to cryptographically link to off-chain legal documentation through `attachDocument()` and `lookupDocument()` functions.

Key Features

- **Granular lifecycle control.** Four separate checking functions (`transfer`, `transferFrom`, `mint`, `burn`) enable context-specific validation and compliance rules varying by transaction type.
- **Document management.** On-chain linking to legal documents (prospectuses, agreements) via content hashes provides cryptographic proof of documentation and audit trails.
- **Context-aware validation.** Separate `transfer` versus `transferFrom` checking recognizes that exchange or DEX transfers may need different rules than peer-to-peer wallet transfers.
- **Implementation flexibility.** Functions return error codes with human-readable messages but do not prescribe specific compliance logic or architectural patterns.

Status	Draft
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Prescriptive Spectrum	48% (interface-defined with implementation flexibility)
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Adoption	Minimal (ATLANT reference implementation only)
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Best For	Granular compliance checking with document management (theoretically)
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Current Status

ERC-1462 achieved Draft status in October 2018, representing a historical milestone as the first merged EIP for general security tokenization, yet never progressed beyond that recognition. ATLANT's real estate tokenization focus does not appear to have materialized at scale, leaving the standard without meaningful production validation. Seven years later, the standard remains orphaned. It is technically sound in design but practically irrelevant in an ecosystem that consolidated around ERC-3643's comprehensive approach for complex needs and ERC-1404's simplicity for basic requirements. The granular checking pattern and document management represent ideas the market determined unnecessary, choosing either comprehensive systems or minimal interfaces over the middle ground ERC-1462 occupies.

When to Use

Theoretically suitable for securities requiring granular lifecycle controls where minting, burning, and different transfer contexts demand distinct validation logic. The document management features appeal to offerings where cryptographic proof of legal documentation matters, such as

linking prospectuses, subscription agreements, or regulatory filings on-chain. Context-aware checking benefits tokens expecting different compliance requirements for exchange trading versus direct wallet transfers, or scenarios where delegated transfer authority (via approve/transferFrom) requires elevated validation.

When NOT to Use

With essentially zero ecosystem adoption beyond ATLANT's reference implementation and seven years without gaining traction, ERC-1462 represents a standard that newer projects should avoid. The granular four-function approach adds complexity without corresponding benefits for most use cases. ERC-1404's simpler two-function interface or ERC-3643's comprehensive system both prove more practical in production. Document management, while conceptually valuable, has no production usage validating the approach.

ERC-1404: Simple Restricted Token Standard

ERC-1404 defines the simplest possible compliance interface through just two functions. Created by TokenSoft in September 2018 after consulting with securities law firms and major exchanges, the standard intentionally avoids prescribing implementation details. It provides the interface where restriction logic executes and how failures communicate to users, but leaves all compliance mechanisms (whitelists, lockups, jurisdiction rules) entirely to implementers. This minimalism enables maximum flexibility while ensuring consistent error reporting across different tokens.

Key Features

- **Pre-flight validation.** View function enables wallets and exchanges to check transfer validity before execution, preventing failed transactions and improving user experience.
- **Vendor neutrality.** Zero prescription of compliance implementation (no mandated identity systems, registries, or architectural patterns) prevents lock-in to service providers.
- **Human-readable errors.** It's function standardizes user-facing error communication, essential for regulatory compliance and investor experience.
- **Minimal overhead.** Simple interface adds only 5,000 to 15,000 gas versus standard ERC-20 transfers, significantly cheaper than comprehensive compliance systems.

Status	Draft (GitHub issue, not official EIP)
Prescriptive Spectrum	36% (minimal interface, maximum implementation flexibility)
Adoption	Moderate (SEC filings, TokenSoft platform, limited ecosystem)
Best For	Simple compliance needs (basic whitelists, lockups, flowback prevention)

Current Status

ERC-1404 exists as a GitHub issue rather than official EIP, achieving Draft-equivalent recognition in 2018 without formal standardization process completion. Despite this unofficial status, the standard achieved meaningful adoption. Multiple SEC EDGAR filings reference it, TokenSoft's platform deployed it for client offerings, and the CMTA (Swiss Capital Markets and Technology Association) integrated detectTransferRestriction logic into their CMTAT standard. However, adoption remains concentrated in TokenSoft's ecosystem without broader developer community or institutional consortium backing. The standard proved that minimalism works for simple use cases but cannot compete with comprehensive systems for complex institutional requirements, settling into a role as the lightweight alternative for basic compliance needs.

When to Use

Suitable for securities offerings with straightforward compliance requirements where more comprehensive infrastructure would be disproportionate. Basic KYC whitelists, simple lockup periods, or Regulation S flowback prevention

(which legal counsel specifically praised for enabling) represent natural use cases. Single-token issuances where modular reusability provides no benefits, cost-sensitive applications where minimizing gas overhead matters, and rapid deployment scenarios prioritizing time-to-market over comprehensive features. The standard's regulatory validation through multiple SEC EDGAR filings demonstrates that minimalism can satisfy securities law requirements when use cases remain straightforward.

When NOT to Use

Insufficient for complex multi-jurisdictional securities requiring sophisticated identity management, recovery mechanisms, or dynamic compliance rule updates. Lacks the comprehensive infrastructure institutional buyers expect, including ONCHAINID, built-in KYC verification, and agent powers for corporate actions. The seven-year Draft status without progression toward Final indicates standardization limitations, though production usage demonstrates practical viability despite the perpetual Draft state.

ERC-2009: Compliance Service

ERC-2009 defines a multi-token compliance service architecture where a single smart contract validates transfers for multiple security tokens simultaneously. Proposed by Daniel Lehrner (io.builders) in May 2019 with collaborative implementation by adhara.io, the standard introduces `check(address token, address from, address to, uint256 amount)` enabling centralized compliance management. One service contract handles validation for an entire platform's token offerings. The service pattern aims to reduce deployment costs (one comprehensive service versus many token-embedded compliance contracts) and enable unified rule management (update a whitelist once and it affects all connected tokens), targeting platforms issuing multiple securities to shared investor bases.

Key Features

- **Centralized compliance management.** Single service contract validates transfers for multiple tokens, reducing duplicated logic and enabling platform-wide rule consistency.
- **Shared infrastructure efficiency.** Deploy whitelists, lockups, and jurisdiction rules once and reference them across many token offerings, amortizing development and gas costs.
- **Instant propagation.** Update investor eligibility in the service contract and all connected tokens immediately recognize changes without individual modifications.
- **Comprehensive validation.** Includes various checking functions plus update functions for state tracking and token management functions.

Status	Draft
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Prescriptive Spectrum	36% (service pattern framework)
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Adoption	Very limited (collaborative implementation by adhara.io/io.builders, minimal ecosystem)
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Best For	Multi-token platforms with shared compliance infrastructure (theoretically)
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Current Status

ERC-2009 achieved Draft status in May 2019 and remains there six years later without progression or meaningful ecosystem adoption. The standard was collaboratively implemented by enterprise blockchain companies adhara.io and io.builders (which merged in June 2025), but no broader public implementations, developer community, or institutional backing emerged. The market revealed that multi-token compliance service architecture solves a problem very few platforms actually face. Most launch single securities, and those managing portfolios prefer either per-token compliance independence or comprehensive integrated systems. The standard illustrates that theoretical efficiency gains do not drive adoption without corresponding real-world demand.

When to Use

Theoretically optimal for platforms issuing five or more security tokens to overlapping investor bases where shared compliance infrastructure provides genuine economies of scale. Centralized KYC management benefits scenarios where the same accredited investors participate across multiple offerings. Add them to the platform service once rather than whitelisting per token. Platforms

prioritizing consistent compliance rules across all securities, where unified policy management and instant rule propagation justify the external dependency and architectural complexity.

When NOT to Use

Minimal adoption beyond the implementing companies after six years indicates the use case is far narrower than anticipated. Most issuers launch single tokens, not platforms with many offerings, eliminating the reusability benefits that justify service pattern complexity. The external dependency creates concerns. Service downtime blocks all token transfers, service compromise affects the entire platform, and centralization risks conflict with decentralization principles. For single-token offerings, ERC-1404's inline checking proves simpler.

ERC-2980: Swiss Compliant Asset Token

ERC-2980 defines an interface for asset tokens compliant with Swiss law and FINMA guidance. Proposed by the Noku team in 2020 as an ERC-20 compatible token with Swiss securities law compliance, the standard mandates alignment with the Swiss Stock Exchange Act, Banking Act, Financial Market Infrastructure Act, Collective Investment Schemes Act, and Anti-Money Laundering Act while also aiming to meet European jurisdiction requirements. It introduces Whitelist and Frozenlist mechanisms managed by privileged Issuer roles, alongside revoke/reassign functions addressing FINMA requirements that ERC-1404 could not satisfy.

Key Features

- **Dual-list compliance architecture.** Whitelist members can receive tokens . Frozenlist members are completely frozen from sending or receiving.
- **Issuer role with elevated privileges.** Manage whitelists and frozenlists, execute freeze functions, revoke tokens and reassign them, transfer issuer role to another address.
- **Swiss regulatory specificity.** Explicitly designed for FINMA asset token requirements including mandatory freeze/revoke capabilities that Swiss law demands for securities.
- **Backward ERC-20 compatibility.** Implements standard transfer, transferFrom, approve, allowance functions while adding the compliance layer. decimals() returns 0 when implemented.

Status	Stagnant (inactivity, no implementations)
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Prescriptive Spectrum	32%
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Adoption	None (zero production deployments)
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Best For	Not recommended for use (theoretical framework never implemented)
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Current Status

ERC-2980 achieved Stagnant status after prolonged inactivity. The standard represents a well-intentioned effort to codify Swiss FINMA requirements (freeze, revoke, whitelist) that legitimately exceeded ERC-1404's capabilities, authored by Switzerland-based Noku's blockchain team targeting their home jurisdiction's securities laws. However, no official implementation ever materialized despite detailed interface specifications, no production deployments emerged, and the proposal died from neglect rather than strategic pivot. The standard's primary value lies in documenting Swiss regulatory requirements circa 2020 and demonstrating why jurisdiction-specific tokenization standards struggle. Even when addressing genuine legal needs, fragmentation and lack of implementation focus limit specialized frameworks against comprehensive universal alternatives.

When to Use

This standard never saw production usage despite theoretical applicability to Swiss securities tokenization. The standard aimed to address genuine FINMA requirements around reissuing securities to investors and enforcing transfer restrictions through

freeze/revoke functions, needs that ERC-1404's simpler approach could not satisfy. However, the Noku team never presented an official implementation, and the standard stagnated due to inactivity after achieving Draft status.

When NOT to Use

Avoid this standard entirely. Beyond zero production deployments, fundamental issues limit the approach. Jurisdictional specificity fragments ecosystems without corresponding benefits, as Swiss issuers need international investor access. The framework lacks reference implementations despite detailed specifications. Elevated Issuer privileges create centralization risks and security considerations absent in standard ERC-20 tokens. The standard's Stagnant status resulted from inactivity rather than deliberate abandonment. The GitHub discussion issue closed due to lack of response to editor feedback, multiple review attempts failed, and the proposal died from neglect. Modern comprehensive standards provide superior Swiss law compliance while supporting global operations.

ERC-7943: Universal RWA Interface (uRWA)

ERC-7943 defines a minimal, implementation-agnostic interface for tokenized real-world assets, designed to work across ERC-20, ERC-721, and ERC-1155 token types simultaneously. The standard is backed by an 11-firm coalition. Five core functions span compliance checks and enforcement actions. The inclusion of enforcement actions distinguishes ERC-7943 from earlier lightweight standards like ERC-1404, which focused exclusively on transfer restriction checking. The 24% prescriptive spectrum score reflects function signatures defined without mandating identity systems, compliance architectures, or registry structures. The standard notes backward compatibility with ERC-3643 and ERC-7518 naming conventions.

Key Features

- **Token-type agnosticism.** Reference implementations for ERC-20, ERC-721, and ERC-1155 enable a single compliance interface across fungible securities, unique physical assets, and multi-token fund structures.
- **Enforcement actions included.** Address regulatory requirements without prescribing access control mechanisms.
- **DeFi composability by design.** Protocols can call `canTransact()` or `canTransfer()` to handle compliant RWA tokens without custom integration per standard.
- **Implementation agnosticism.** Compliance checks can be backed by whitelists, ONCHAINID, Merkle proofs, zero-knowledge proofs, or any other verification method.

Status	Review (submitted June 2025)
Prescriptive Spectrum	24% (minimal interface, maximum implementation flexibility)
Adoption	None (no production deployments as of February 2026)
Best For	Multi-token-type RWA compliance with DeFi composability (proposed)

Current Status

ERC-7943 entered Review status in July 2025, approximately one month after submission. The standard's trajectory depends on whether DeFi protocols add native support, whether coalition members commit to production deployments, and whether the specification stabilizes through the EIP process. These questions cannot be answered with available data, and this report will revisit its status in future editions as adoption data emerges.

When to Use

Potentially suitable for projects requiring a lightweight compliance interface across multiple token types, particularly those prioritizing DeFi

composability. Projects exploring novel RWA categories (carbon credits, intellectual property, commodities) that do not fit cleanly into existing securities-specific frameworks may find ERC-7943's token-agnostic flexibility appealing.

When NOT to Use

As of February 2026, ERC-7943 has no production deployments, no audited reference implementations, and no regulatory engagement at the standard level. Active Ethereum Magicians discussions indicate the specification has not yet stabilized. The coalition firms are predominantly Web3 tokenization platforms and infrastructure companies.

ERC-1592: Address and ERC20-Compliant Transfer Rules

ERC-1592 defines a modular rule engine architecture that externalizes compliance logic into separate, reusable rule contracts rather than embedding restrictions within token contracts. Proposed by Mt Pelerin in November 2018, the standard introduces the IRule interface with two methods: `isAddressValid(address)` for holder eligibility and `isTransferValid(from, to, amount)` for transfer parameters. This enables tokens to attach multiple independent rule contracts that execute in sequence. The architecture emphasizes reusability. The same KYC whitelist rule can serve multiple tokens, the same lockup rule can be deployed once and referenced by many offerings, and updating compliance requires deploying new rule contracts rather than modifying token logic.

Key Features

- **Modular composition.** Compliance rules live in separate contracts implementing the IRule interface, enabling mix-and-match composition for complex regulatory requirements.
- **Reusability across tokens.** Deploy a KYC rule once, attach it to multiple security tokens, reducing code duplication and gas costs at ecosystem scale.
- **Post-deployment updates.** Change compliance rules by calling `defineRules()` with new rule contracts. No token contract migration required for evolving regulations.
- **Pre-flight validation.** View functions enable wallets and exchanges to query `isAddressValid()` and `isTransferValid()` before attempting transfers, improving user experience.

Status	Draft
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Prescriptive Spectrum	40% (modular rule engine framework)
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Adoption	Limited (Mt Pelerin MPS token only)
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Best For	Frequently changing compliance requiring modular rule composition
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Current Status

ERC-1592 achieved Draft status in November 2018 and demonstrated production viability through Mt Pelerin's MPS token, described as the first regulated tokenized company share issued under Swiss law in 2018. The token's ability to update compliance rules multiple times post-issuance validated the framework's flexibility advantage. However, six years later, no meaningful secondary adoption emerged beyond Mt Pelerin's ecosystem. The market has thus far indicated that institutional adopters prioritize proven comprehensive infrastructure over architectural flexibility. The standard represents an evolutionary step in securities tokenization, demonstrating a technically valid concept that the ecosystem ultimately passed over in favor of more comprehensive alternatives.

When to Use

Best suited for platforms issuing multiple securities where shared compliance infrastructure provides genuine efficiency gains. Deploying one KYC

registry and reusing it across ten token offerings amortizes development and auditing costs. Valuable when regulations change frequently post-issuance, as Mt Pelerin's MPS token demonstrated by updating rules multiple times during the tokensale without contract migration. The modular architecture benefits sophisticated compliance scenarios requiring composition of many validation layers (KYC, accreditation, jurisdiction, lockup, holder limits, trading hours) where inline logic becomes unwieldy.

When NOT to Use

Avoid for single-token offerings where the modular overhead provides no reuse benefits. The complexity of external rule contracts, array iteration, and multiple storage reads adds gas costs (30,000 to 100,000+ per transfer) without corresponding value. ERC-1404's inline checking proves simpler and cheaper for standalone projects. The rule engine pattern requires sophisticated development teams comfortable with multi-contract architectures.

ERC-7518: Dynamic Compliant Interoperable Security Token (DyCIST)

ERC-7518 defines a security token standard that extends ERC-1155 to support partitioned, semi-fungible tokens with dynamic compliance and cross-chain interoperability. Authored by the ZoniqX engineering team and submitted in September 2023, the standard introduces a partition model where each tokenId represents a distinct segment (share class, tranche, or series) with its own compliance rules, transfer restrictions, and corporate action logic within a single contract. Enforcement capabilities include token locking for vesting or holding periods, forced transfers for key recovery, and address freezing for compliance actions. Dynamic compliance is managed through off-chain vouchers that validate transfers against jurisdictional requirements at execution time, allowing rules to evolve without redeploying contracts. A wrapping mechanism for ERC-3643 tokens enables conversion between the two standards through a lock-and-mint process preserving compliance state. The 24% prescriptive spectrum score reflects interface functions and partition semantics defined without mandating specific compliance architectures or identity systems.

Key Features

- **Partition-aware token model.** Each tokenId represents a distinct share class, tranche, or series with independent compliance rules, fee structures, and transfer windows within a single contract.
- **Cross-chain compliance by design.** Supports token movement across EVM-compatible chains and non-EVM chains through standardized wrapping mechanisms and compliance-aware bridging.
- **Dynamic compliance management.** Off-chain vouchers validate transfers against current jurisdictional requirements at execution time rather than at issuance.
- **ERC-3643 interoperability.** Token wrapping mechanism locks ERC-3643 tokens and mints equivalent ERC-7518 tokens, enabling conversion while preserving compliance metadata.

Status	Draft (submitted September 2023)
Prescriptive Spectrum	24% (interface-defined with maximum implementation flexibility)
Adoption	Early production (ZoniqX platform, \$100M+ tokenized real estate announced on Hedera)
Best For	Multi-class securities requiring partitioned ownership, cross-chain compliance, and semi-fungible token structures

Current Status

ERC-7518 achieved Draft status in September 2023 and has undergone a CertiK security audit. ZoniqX and StegX announced a \$100M+ tokenized real estate launch on Hedera for three European family office portfolios. ZoniqX reports broader platform activity, though independent on-chain verification is not immediately publicly available. The standard's trajectory depends on whether adoption extends beyond ZoniqX's own platform.

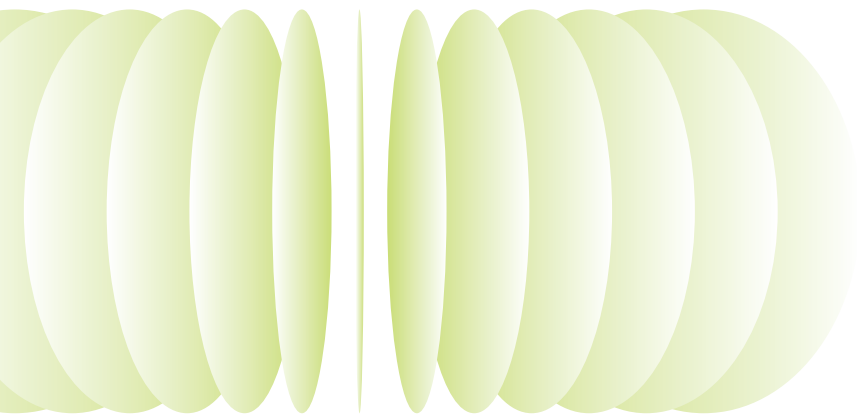
When to Use

Potentially suitable for structured securities requiring multiple share classes or tranches within a single contract, where ERC-1155's multi-token capabilities

provide genuine architectural advantages. Real estate funds with different investor tiers, private equity vehicles with senior and junior tranches, or multi-series bond programs represent natural use cases.

When NOT to Use

ERC-7518 is closely tied to ZoniqX's commercial platform. While the EIP is open, the tooling, compliance infrastructure (CompliTO), and implementation expertise are concentrated within a single vendor. For straightforward fungible securities without partition requirements, ERC-20-based standards remain simpler and better supported across wallets, exchanges, and DeFi protocols.



The Securities Standards Landscape

Six standards attempted different points along the prescriptive-flexible spectrum. ERC-1462 (48%) offered granular checking the market passed over as unnecessary middle ground. ERC-1592 (40%) demonstrated modular rule composition through Mt Pelerin's MPS token but gained no broader ecosystem. ERC-1404 (36%) achieved SEC regulatory validation yet remained confined to simple use cases. ERC-2009 (36%) solved a multi-token compliance problem few platforms actually face. ERC-2980 (32%) fragmented markets with Swiss-specific requirements and died from neglect.

Among the 2018-2020 generation, ERC-3643's 100% comprehensive prescription attracted the adoption that flexible alternatives did not. Securities tokenization at institutional scale has consistently demanded proven and audited compliance infrastructure, identity management with recovery mechanisms, regulatory confidence from prescriptive architecture, consortium backing (100+ members), and production validation at scale (\$28 to \$32 billion).

ERC-7943 represents a distinct test case. It arrives with multi-firm coalition backing, targets all RWA token types rather than securities alone, and includes enforcement actions that earlier lightweight standards omitted. Whether these differences produce a different adoption outcome is an open question that will be answered by market data over 2026 and 2027.

Adoption

The historical pattern is clear: among standards with meaningful time in market, comprehensive prescription attracted institutional adoption while flexible frameworks did not. The newer entrants introduce variables earlier standards lacked. ERC-7518 offers partitioned multi-class securities and cross-chain compliance, though its ecosystem remains concentrated around Zoniqx. ERC-7943 offers coalition backing and a minimal universal interface, though no production data yet exists.

Standard	Prescriptive %	Production Usage	Institutional Backing
ERC-1404	36%	SEC filings, niche usage	TokenSoft platform
ERC-1592	40%	MPS token only	Mt Pelerin only
ERC-1462	48%	None	ATLANT reference
ERC-2009	36%	Collaborative implementation	adhara.io / io.builders
ERC-2980	32%	None (abandoned)	Noku team only
ERC-7518	24%	\$100M+ announced (Hedera)	Zoniqx platform
ERC-7943	24%	None (submitted June 2025)	11-firm coalition

Bonds

Derivatives

Distribution

Standards

Bonds and derivatives represent some of the most sophisticated financial instruments in traditional markets, and correspondingly, some of the most challenging assets to tokenize on blockchain infrastructure. Unlike equity shares, which represent straightforward ownership stakes, bonds and derivatives involve complex temporal mechanics, multi-party relationships, intricate cash flow calculations, and state-dependent behaviors that strain the capabilities of smart contract architecture. Beyond representing these instruments, successful tokenization requires infrastructure for automated payment distribution, replacing traditional paying agents with programmable smart contracts that handle interest, coupon, and redemption payments without manual intervention.

The four standards examined in this section represent different approaches to these interconnected challenges. ERC-3475 provides an abstract storage framework capable of representing virtually any bond structure through flexible metadata. ERC-6123 tackles the broader derivatives market with a state-machine architecture for managing complex instrument lifecycles. ERC-7092 takes a pragmatic approach by using traditional finance terminology to ease institutional adoption. ERC-2222 addresses the payment infrastructure layer, enabling automated distribution of interest, coupons, or profits to token holders. These standards occupy positions ranging from 40% to 48% on the prescriptive spectrum, reflecting varying philosophies about structure versus flexibility. Current adoption remains limited across all four, with only ERC-2222 demonstrating production viability through Maple Finance's lending protocol.

ERC-6123: Smart Derivative Contracts

ERC-6123 addresses the unique challenges of derivative instruments through a state-machine architecture managing complex instrument lifecycles. Unlike bonds with relatively predictable cash flows, derivatives involve conditional logic, dynamic valuations, settlement triggers, and collateral management that must respond to real-world events. The standard provides a structured progression through defined lifecycle stages: inception, active trading, settlement trigger, and final settlement or termination. The philosophical approach emphasizes separating the contract specification (what parties agreed to) from contract valuation (what it is currently worth) and the settlement mechanism (how payments execute), allowing the same standard to represent forwards, futures, options, swaps, and exotic derivatives by varying parameters and settlement logic while maintaining consistent external interfaces.

Key Features

- **State-machine lifecycle management.** Contracts transition through Inception, Active, Matured, and Settled states with specific functions available at each stage, preventing invalid operations like settling before maturity.
- **External valuation engine architecture.** Defines interfaces for off-chain pricing systems to provide mark-to-market valuations, acknowledging that complex derivative pricing belongs in specialized systems rather than on-chain logic.
- **Broad derivative applicability through parameterization.** Framework accommodates forwards, futures, options, swaps, and exotic derivatives without prescribing specific contract types or settlement formulas.

Status	Draft
Prescriptive Spectrum	44% (lower-medium framework with lifecycle structure)
Adoption	Minimal (no major production deployments identified)
Best For	Derivatives desks building sophisticated infrastructure with external pricing engines and oracle integration

Current Status

ERC-6123 achieved Draft status in 2022, representing sophisticated architectural thinking from quantitative finance experts about how blockchain infrastructure could support derivatives markets. The standard's separation of concerns (contract specification versus valuation versus settlement) demonstrates deep understanding of traditional derivatives operations and realistic assessment of smart contract limitations. However, no production deployments have validated the approach at scale. The compounding challenges of oracle reliability, collateral management complexity, regulatory ambiguity, and network effect requirements (derivatives markets need deep liquidity and standardized infrastructure) have prevented the breakthrough adoption needed to establish momentum. While the standard provides a technically sound starting point for institutions exploring derivatives tokenization, realistic timelines extend to 2027-2030 for meaningful production scale as oracle infrastructure matures, regulatory frameworks clarify, and institutional comfort with blockchain settlement develops.

When to Use

Appropriate for derivatives trading desks or institutional platforms building sophisticated infrastructure that can integrate external pricing

engines, maintain oracle data feeds, and implement complex settlement logic. The state-machine architecture benefits organizations managing derivative lifecycles where preventing invalid state transitions (trading after termination, settling before maturity) provides genuine risk reduction. Best suited for pilots and proofs-of-concept exploring blockchain-based derivatives feasibility rather than immediate production deployment, given the standard's unproven status.

When NOT to Use

Avoid for production deployments requiring proven infrastructure. Zero identified implementations managing real derivatives despite years since proposal indicates significant unresolved challenges. The oracle dependency creates centralization concerns and potential manipulation vectors that the 2012 LIBOR scandal demonstrates as existential risks to derivatives markets. Regulatory uncertainty remains acute for smart contract settlement authority versus traditional ISDA frameworks, with most jurisdictions lacking legal clarity on enforceability. Organizations seeking simple fixed-income instruments should use bond standards (ERC-7092, ERC-3475) rather than derivatives frameworks.

ERC-3475: Abstract Storage Bonds

ERC-3475 provides a generalized framework for representing bonds as tokens with rich, structured metadata that can accommodate virtually any bond type. Rather than prescribing specific bond mechanics or payment structures, the standard establishes a flexible storage architecture where each bond carries arbitrary parameters: coupon rates, maturity dates, payment frequencies, amortization schedules, callable features, and any other attributes required by the instrument. The standard's core innovation lies in its "class" and "nonce" system. Each bond issuance represents a class, while individual holdings within that class are represented by nonces. This structure enables efficient batch operations, standardized queries across different bond types, and compatibility with existing DeFi infrastructure expecting fungible-like behavior within classes.

Key Features

- **Universal applicability through metadata abstraction.** JSON-like key-value storage accommodates everything from simple bullet bonds to complex structured products within a single technical framework.
- **Class-based organization for efficient operations.** Batch transfers, redemptions, and queries across multiple bonds in single transactions reduce gas costs for portfolio management.
- **DeFi-compatible fungibility within classes.** Bonds of the same class behave like fungible tokens, enabling integration with DEXs, lending protocols, and yield aggregators.
- **Future-proof extensibility.** Abstract design accommodates novel bond structures not yet invented by allowing custom metadata keys beyond standard parameters.

Status	Draft
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Prescriptive Spectrum	48% (medium framework with flexible metadata)
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Adoption	Minimal (no major production deployments identified)
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Best For	Universal bond issuers requiring maximum flexibility for diverse or exotic bond structures
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Current Status

ERC-3475 achieved Draft status in 2020 and represents technically sound architecture for flexible bond representation, yet remains unproven in production environments. No major institutional deployments, DeFi integrations, or secondary market implementations have emerged to validate the approach at scale. The standard occupies a middle ground that has not attracted adoption. It is more complex than simple interfaces but less comprehensive than full systems, offering flexibility the bond market has not yet demanded. While the class/nonce architecture and metadata abstraction demonstrate sophisticated design thinking, the four-year adoption gap suggests that bond tokenization requires either simpler approaches for basic instruments or comprehensive infrastructure for complex ones, not abstract frameworks requiring significant custom development.

When to Use

Best suited for organizations managing diverse bond programs requiring flexible metadata accommodation. Sovereign debt offices issuing bonds across multiple currencies and maturities, structured product desks creating bespoke instruments with complex payment waterfalls, or platforms building

universal bond infrastructure intended to support many issuers with varying needs. The abstraction provides genuine value when bond diversity justifies the implementation complexity, particularly for issuers expecting to tokenize exotic structures (convertibles, step-up coupons, participation bonds) that prescriptive standards cannot accommodate.

When NOT to Use

Avoid for single-issuer scenarios with standard bond structures where the metadata flexibility provides no benefit. ERC-7092's prescriptive conventions prove simpler for plain-vanilla fixed-rate bonds. The abstract framework offers no guidance on crucial implementation details (interest calculation methods, day-count conventions, default handling), forcing implementers to build these from scratch and creating interoperability challenges when different implementations make incompatible choices. The complete absence of major production deployments after four years indicates the market prefers either comprehensive systems or prescriptive standards over abstract middleware.

ERC-7092: Financial Bonds

ERC-7092 takes a fundamentally different approach from abstract frameworks by implementing bonds using the precise terminology and conventions of traditional capital markets. Created in May 2023, the standard's explicit goal is reducing the cognitive barrier for institutional finance professionals unfamiliar with blockchain by using familiar concepts rather than forcing translation between TradFi and DeFi mental models. This philosophy manifests in detailed specification of bond mechanics. The standard prescribes specific calculations for accrued interest, defines standard coupon payment frequencies and provides methods matching traditional bond operations including yield-to-maturity calculations and clean versus dirty pricing. The standard essentially codifies fixed-income market practices into smart contract interfaces.

Key Features

- **Traditional finance terminology and conventions.** Uses principal, coupon, maturity, and day-count concepts familiar to fixed-income professionals, eliminating translation effort and reducing adoption friction.
- **Precise day-count calculation standards.** Implements actual/360, 30/360, and actual/actual methods matching market conventions. This precision is critical for avoiding pricing discrepancies.
- **Secondary market support through clean/dirty pricing.** Calculates both clean price and dirty price for accurate mid-period trading where buyers compensate sellers appropriately.
- **Institutional audit compatibility.** Traditional finance auditors can verify calculations against known standards without learning blockchain-specific approaches.

Status	Final
Prescriptive Spectrum	48% (medium framework with precise calculation conventions)
Adoption	Minimal (no major production deployments identified)
Best For	Conservative institutions issuing standard bonds who prioritize familiar conventions over technical flexibility

Current Status

ERC-7092 achieved Final status, making it the only bond-specific standard in this section to complete the full EIP process. The standard also includes cross-chain functionality specifications for bond operations across multiple blockchains. However, achieving Final status has not yet translated into production adoption. No major institutional deployments have emerged to validate the approach at scale. The persistent zero-adoption pattern across all bond standards suggests that technical design choices matter less than resolving fundamental challenges: regulatory clarity for tax treatment and legal enforceability, oracle infrastructure for benchmark rates, and network effects enabling liquid secondary markets. ERC-7092's Final status and institutional terminology positioning make it potentially the best-situated bond standard for eventual adoption when these systemic barriers resolve, but realistic timelines extend to 2027-2030.

When to Use

Suitable for conservative financial institutions taking first steps into tokenization who prioritize familiar territory over technical innovation. Banks issuing digital bonds, corporate treasuries exploring blockchain settlement, or government entities piloting tokenized debt programs represent natural adopters. The prescriptive day-count conventions and accrual

calculations benefit scenarios where integration with traditional bond analytics systems matters, enabling pricing models and risk systems to consume tokenized bonds without modification. Best suited for standard fixed-rate or floating-rate bonds where the prescriptive approach accommodates the instrument structure naturally.

When NOT to Use

Avoid for exotic bond structures (convertibles, step-up coupons, complex amortization schedules, participation bonds) where the prescriptive approach forces instruments into ill-fitting templates. ERC-3475's metadata flexibility better accommodates non-standard structures. The standard provides no default mechanism for handling issuer defaults, credit rating changes, or restructuring events that represent significant practical concerns for real-world bonds. Oracle requirements for interest rate benchmarks (SOFR, EURIBOR) create operational dependencies and centralization risks. Despite institutional terminology alignment, the complete absence of major deployments indicates that familiar conventions alone prove insufficient to overcome broader adoption barriers affecting all bond tokenization standards.

ERC-2222: Dividend Distribution Token

ERC-2222 extends ERC-20 with automated profit distribution, enabling tokens to programmatically distribute payments to holders without manual intervention. The standard adds three core functions used for holders to claim, and for issuers to allocate funds proportionally. Despite its name, the primary use case involves distributing interest payments in lending protocols rather than equity dividends, functioning as a coupon distribution mechanism.

Maple Finance's MPL token (2021-2024) demonstrated the standard's viability at scale, using ERC-2222 to distribute USDC profits from treasury to token holders while originating \$4B+ in institutional loans. However, Maple has since migrated to ERC-4626-based vault architecture with their SYRUP token, reflecting the market's evolution toward vault standards for yield-bearing assets.

Key Features

- **Automated pro-rata calculation.** System automatically determines each holder's share based on their token balance relative to total supply, eliminating manual payment calculations.
- **Claim-based distribution model.** Holders withdraw payments when convenient rather than receiving automatic transfers, reducing gas costs and enabling batched claiming.
- **Multiple payment token support.** Distributions can occur in any ERC-20 token, not just the token's native denomination.
- **Proven DeFi production usage.** Maple Finance demonstrates viability at scale with over \$4 billion in loans originated using automated interest distributions to liquidity pool participants.

Status	Draft
Prescriptive Spectrum	40% (minimal framework for payment distribution)
Adoption	Proven (Maple Finance with \$4B+ in loans originated)
Best For	DeFi lending protocols and yield-bearing assets requiring automated interest or profit distribution

Current Status

ERC-2222 achieved Draft status in July 2019 and demonstrated production viability through Maple Finance's implementation (2021-2024), which successfully distributed profits while the platform originated \$4B+ in institutional loans. The on-chain MPL token contract directly imports and extends ERC-2222, providing verifiable evidence of production usage. This proved the standard's technical soundness and scalability.

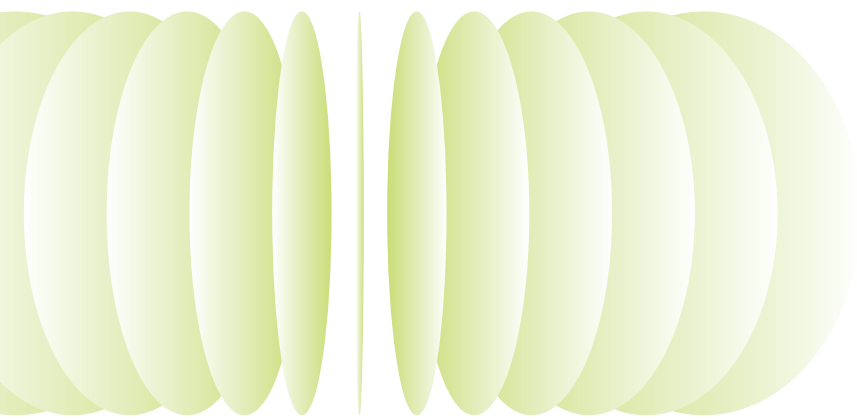
However, the DeFi ecosystem has evolved. Maple migrated to ERC-4626-based revenue distribution with their SYRUP token in late 2024, and new protocols overwhelmingly favor ERC-4626's vault standard over ERC-2222's simpler distribution model. The standard exists in a transitional state. It is historically successful and technically proven, but functionally superseded by ERC-4626 for most yield-bearing token use cases. ERC-4626 offers superior DeFi composability, more comprehensive functionality, and Final status versus Draft. While ERC-2222 served an important role in demonstrating automated distributions work at scale, it represents a stepping stone toward vault-based architectures rather than the current best practice.

When to Use

Appropriate for DeFi lending protocols where liquidity providers earn interest on deployed capital, though ERC-4626 vaults are now the preferred standard for new implementations. Suitable for yield-bearing tokens with simple distribution requirements where full vault functionality is unnecessary. The claim-based model benefits scenarios with many holders where automatic transfer gas costs would be prohibitive. Best for organizations already committed to this specific architecture or maintaining legacy systems.

When NOT to Use

Avoid for traditional securities requiring tax reporting, as there is no mechanism for 1099-DIV forms or regulatory compliance. New projects should strongly consider ERC-4626 instead, which offers comprehensive vault functionality, superior DeFi composability, and broader ecosystem adoption. The claim-based model creates UX friction for retail users expecting automatic payments. Organizations requiring guaranteed payment delivery should use traditional rails rather than claim-based systems.



Comparative Analysis

The four standards in this section address complementary layers of fixed-income tokenization infrastructure. ERC-3475, ERC-6123, and ERC-7092 focus on representing instruments and their complex attributes, while ERC-2222 tackles the orthogonal problem of distributing payments once instruments exist.

The instrument representation standards occupy similar positions on the prescriptive spectrum (44-48%), reflecting shared tension between providing sufficient structure for interoperability while maintaining flexibility for diverse financial products. ERC-3475's metadata abstraction maximizes instrument diversity at the cost of implementation complexity. ERC-6123's state-machine architecture addresses derivatives' unique lifecycle challenges through external valuation engines. ERC-7092's traditional finance terminology prioritizes institutional familiarity over technical innovation. ERC-2222 sits at 40%, providing minimal structure beyond core distribution functions while leaving implementation details to adopters.

Adoption

The adoption pattern reveals a striking divergence. ERC-2222 demonstrates proven production viability through Maple Finance's \$4B+ lending protocol, while the three instrument standards show zero meaningful deployment despite addressing markets worth hundreds of trillions. This gap stems from fundamentally different challenges. ERC-2222 solves a self-contained technical problem (automated payment distribution) that DeFi protocols can adopt immediately without broader ecosystem coordination, regulatory clarity, or network effects. The instrument standards face compounding systemic barriers: oracle dependencies for pricing and benchmark data create centralization risks, regulatory uncertainty about tax treatment and legal enforceability prevents institutional commitment, and network effect requirements create problems where issuers need platforms and platforms need issuances.

ERC-2222's greatest potential value lies in traditional securities (automating dividend and coupon payments) yet adoption remains confined to DeFi due to tax reporting ambiguity, demonstrating how regulatory gaps prevent technically successful standards from reaching their natural markets. For institutions evaluating blockchain strategies, bonds and derivatives tokenization represents a 2027-2030 opportunity as infrastructure and regulatory frameworks mature, while automated distributions await clarity on compliance obligations before crossing from DeFi into traditional finance.



Physical

Assets

Standards

Tokenizing physical assets represents blockchain's most ambitious bridge between digital ledgers and the physical world. Unlike securities where ownership records migrate from centralized databases to blockchain, physical assets exist in three-dimensional space with possession, custody, and physical state that blockchains cannot directly observe. Gold bars in vaults, luxury watches, real estate properties, and vehicles create the oracle problem at its most acute. How do you cryptographically prove that a specific physical object corresponds to a specific token, that custody matches claimed ownership, and that physical transfers synchronize with on-chain transactions? Proponents highlight fractional ownership of expensive assets, enhanced liquidity for illiquid markets, provenance tracking for authenticity, and 24/7 global trading. Skeptics question whether digital tokens can genuinely represent physical possession. This tension between physical custody and digital ownership rights defines the entire category.

Three distinct technical approaches emerged to address these challenges. Cryptographic chip standards (ERC-4519) embed secure element chips containing private keys directly in physical objects, enabling assets to cryptographically prove their identity. Maximum security comes with the highest per-unit cost (\$5-50) and manufacturing complexity. Simple chip standards (ERC-5791) use basic NFC/RFID chips storing unique identifiers for scan-to-claim workflows. Moderate security with chip cloning risks but dramatically lower cost (\$0.10-1) and simpler manufacturing integration. Oracle-based standards (ERC-6956) eliminate chips entirely, relying on trusted third parties to attest to physical asset state. Zero hardware costs and applicability to existing assets, but requiring trust in oracle networks.

The prescriptive spectrum reveals these differences. ERC-4519 scores 72% through prescribed secure element integration and cryptographic requirements. ERC-5791 achieves 56% by specifying chip-NFT binding patterns while leaving implementation flexible. ERC-6956 scores 52% through oracle attestation patterns with maximum oracle selection flexibility. All three face limited production usage beyond pilots, confronting barriers in manufacturing costs, consumer education, economic viability, and competition from simpler solutions.

ERC-4519: Non-Fungible Tokens Tied to Physical Assets

ERC-4519 defines "SmartNFTs," physical assets and IoT devices containing secure element chips with private keys that enable cryptographic self-authentication on blockchain. The standard prescribes embedding tamper-resistant hardware storing private keys within physical objects, allowing assets to sign messages proving they control specific NFTs without external verification. Unlike passive objects requiring human or oracle authentication, SmartNFT assets actively participate in blockchain transactions. A luxury watch with an embedded secure element can cryptographically prove it is the genuine item linked to NFT #1234. A connected vehicle can sign authentication challenges confirming its digital title. IoT devices can verify themselves to smart home networks.

Key Features

- **Cryptographic self-authentication.** Physical assets contain secure elements generating unforgeable signatures, eliminating reliance on external oracles or manual verification for authentication.
- **Three SmartNFT types.** Single-owner, multi-owner, and composable supporting diverse ownership structures.
- **Lost/stolen protection.** NFT owners can declare assets lost on-chain, disabling the physical possessor's ability to authenticate and preventing thieves from claiming ownership rights.
- **Recovery mechanisms.** Unlike traditional wallets where lost keys mean permanent loss, SmartNFT architecture enables key rotation and social recovery through secure element management.

Status	Final
Prescriptive Spectrum	72% (secure element integration prescribed)
Adoption	Limited (academic implementations, IoT research)
Best For	High-value assets requiring cryptographic authentication (vehicles, industrial equipment, luxury IoT)

Current Status

ERC-4519 achieved Final status, validating technical rigor through Ethereum's standardization process. Production adoption remains confined to academic implementations and IoT research projects from the authoring universities. No major luxury brands, automotive manufacturers, or consumer electronics companies have announced SmartNFT deployments at scale. The gap between Final status and minimal production usage illustrates that technical validation does not guarantee market adoption when economic viability remains unclear.

When to Use

High-value assets where cryptographic authentication justifies secure element costs (\$5-50 per unit). Connected vehicles with existing onboard computers naturally accommodate secure elements for digital title management and theft prevention. Industrial IoT equipment benefits from self-authentication for access control and warranty verification. Luxury goods where brand prestige warrants premium authentication can embed secure elements during manufacturing for unforgeable provenance.

When NOT to Use

Prohibitively expensive for mass-market items where secure element costs exceed item margins. Manufacturing integration requires specialized expertise and production line modifications. Existing assets cannot retrofit secure elements without potentially harming value. Battery-dependent IoT devices require functioning electronics for authentication. Limited production usage despite Final status suggests the security benefits have not justified implementation complexity for most use cases to date.

ERC-5791: Physical Backed Tokens

ERC-5791 pioneered the "scan-to-own" model. Physical items embedded with basic NFC/RFID chips storing unique identifiers are scanned by users with smartphones to claim or verify NFT ownership. Unlike ERC-4519's cryptographic signing, ERC-5791 chips are passive storage devices containing UIDs read by NFC-enabled phones, triggering on-chain claiming workflows or ownership verification. This architectural simplification dramatically reduces per-unit costs and manufacturing complexity, making scan-to-own viable for fashion, streetwear, collectibles, and other consumer goods where cryptographic authentication would be economically prohibitive. The standard prescribes chip-NFT binding mechanisms while leaving claiming logic, verification workflows, and chip infrastructure implementations flexible.

Key Features

- **Low-cost chip integration.** Basic NFC/RFID tags (\$0.10-1 per unit) enable mass-market deployment across fashion, streetwear, and consumer collectibles without prohibitive costs.
- **Multiple claiming patterns.** Manufacture-claim (brand pre-mints NFT, customer activates), verify-then-claim (mint on first scan), and transfer-by-scan (physical possession change triggers on-chain transfer).
- **Anti-counterfeiting for premium goods.** Chip UIDs registered on-chain by authentic brands enable instant verification. Scanning reveals counterfeit items with unregistered or duplicate UIDs.
- **Smartphone-native UX.** Leverages ubiquitous NFC readers in modern smartphones, creating a familiar "tap to verify" experience without specialized hardware requirements.

Status	Draft
Prescriptive Spectrum	56% (chip-NFT binding pattern with flexible implementation)
Adoption	Experimental (fashion/streetwear pilots, limited production)
Best For	Mass-market premium goods requiring authentication (fashion, collectibles, limited editions)

Current Status

ERC-5791 remains in Draft status without progression toward Final. Adoption exists through fashion and streetwear pilots, but no major brand has announced widespread deployment at scale. The standard competes against proprietary chip-NFT systems, simpler QR codes with centralized databases, and consumer skepticism about NFT value. Streetwear and collectibles communities show the most interest, suggesting niche adoption in premium enthusiast markets rather than mainstream consumer goods.

When to Use

Premium consumer goods where anti-counterfeiting and provenance justify NFC chip costs but cryptographic signing would be disproportionate. Fashion brands combating counterfeiting (designer sneakers, luxury apparel, limited drops) benefit from instant scan verification. Physical collectibles (trading cards, memorabilia, merchandise) gain digital twins without expensive secure elements. Brand-building where scan-to-claim NFTs unlock exclusive content or community access. Redemption models where NFTs represent claims on vault-stored assets.

When NOT to Use

Economically unviable for low-value items where even \$0.10-1 chip cost exceeds margins. Security limitations from chip cloning risks make ERC-5791 insufficient for ultra-high-value assets requiring cryptographic guarantees. Existing assets or items where chip embedding harms value cannot utilize scan-to-own without destructive modification. Consumer adoption requires education about scanning benefits and NFT ownership utility. Manufacturing integration still requires production line modifications and quality control.

ERC-6956: Asset-Bound Non-Fungible Tokens

ERC-6956 eliminates physical chip requirements entirely, instead relying on trusted oracle networks to attest to physical asset state, custody, and binding to NFTs. Proposed in April 2023 as the newest physical asset standard, ERC-6956 prescribes an attestation architecture where oracles cryptographically sign statements about assets, confirming vault custody, verifying authenticity, attesting to condition, tracking location, or authorizing transfers. The "anchor" mechanism establishes cryptographic links between specific physical objects and NFT token IDs through oracle attestations rather than embedded chips, while transfer validation requires oracle approval ensuring physical and digital ownership synchronize. This approach trades chip-based trustless verification for oracle-dependent flexible attestations.

Key Features

- **Zero per-unit hardware costs.** No chips to purchase, embed, or maintain. Oracle verification eliminates physical integration expenses, making tokenization economically viable for lower-value assets.
- **Applicable to existing assets.** Works retroactively with items already manufactured or created, unlike chip standards requiring production-time integration. Enables tokenizing vintage wine, antique furniture, or fine art.
- **Rich attestation metadata.** Oracles provide detailed information (condition reports, provenance history, location tracking, authentication certificates) versus chips' binary presence verification.
- **Multi-oracle consensus.** Reduces single-point-of-failure risks through configurable thresholds enabling redundancy and conflict resolution.

Status	Draft
Prescriptive Spectrum	52% (oracle attestation pattern with maximum flexibility)
Adoption	Minimal (oracle infrastructure immature)
Best For	Vault-stored assets, existing items, scenarios where chip integration is impossible or undesirable

Current Status

ERC-6956 remains in Draft status as a relatively recent proposal. Oracle network infrastructure for physical asset attestation remains largely theoretical. Questions about oracle economics, service level agreements, and trust establishment remain unanswered. The standard requires further infrastructure development, service provider emergence, and production experimentation before viability becomes clear. Current adoption is limited to conceptual discussions and early pilots rather than meaningful production usage.

When to Use

Vault-stored valuables where custodians already provide trusted custody and can serve as natural oracles. Gold in secure facilities, fine wine in bonded warehouses, art in gallery storage. Existing high-value items where chip retrofitting would harm value (vintage collectibles, antiques, master artworks). Asset classes requiring rich metadata beyond simple presence verification, including condition assessment, provenance documentation, and authenticity certificates from experts.

When NOT to Use

ERC-6956 remains in Draft status as a relatively recent proposal. Oracle network infrastructure for physical asset attestation remains largely theoretical. Questions about oracle economics, service level agreements, and trust establishment remain unanswered. The standard requires further infrastructure development, service provider emergence, and production experimentation before viability becomes clear. Current adoption is limited to conceptual discussions and early pilots rather than meaningful production usage.

Understanding Physical Integration Options

Physical asset tokenization requires choosing between three hardware architectures, each representing different points on the security-cost-complexity spectrum. Cryptographic chips refer to secure element hardware (physical tamper-resistant microchips) embedded in assets that store private keys and perform cryptographic operations like signing messages. These chips, similar to those in credit cards or hardware wallets, cannot have their keys extracted even with physical access. Simple chips use basic NFC (Near Field Communication) or RFID (Radio-Frequency Identification) tags that store unique identifier numbers readable by smartphones. Unlike secure elements, these chips perform no cryptographic operations and simply return stored data when scanned. Oracle-based approaches eliminate physical hardware entirely, instead relying on trusted third-party services (custodians, authentication experts, shipping companies) to verify asset state and attest to ownership through signed messages.

Technical Trade-Offs

ERC-4519's cryptographic approach provides maximum security. Assets cryptographically prove their identity through unforgeable signatures, eliminating reliance on external verification. However, secure element chips cost \$5-50 per unit and

require sophisticated manufacturing integration including chip programming, tamper-evident placement, and quality control testing. Only newly manufactured items can incorporate secure elements without destroying value.

ERC-5791's simple chip approach balances practicality with moderate security. Basic NFC tags costing \$0.10-1 per unit enable mass-market deployment across fashion and collectibles. Manufacturing integration proves simpler (applying tags during production), though still requiring process modifications. Security limitations emerge from chip cloning possibilities where counterfeiters duplicate UIDs, though this requires specialized equipment and remains difficult at scale.

ERC-6956's oracle model eliminates hardware costs entirely and works retroactively with existing assets. Custodians or authentication services attest to asset state, condition, and ownership through signed blockchain transactions. This approach trades trustless verification for operational flexibility, accepting dependency on oracle availability and requiring ongoing service fees instead of one-time chip costs.

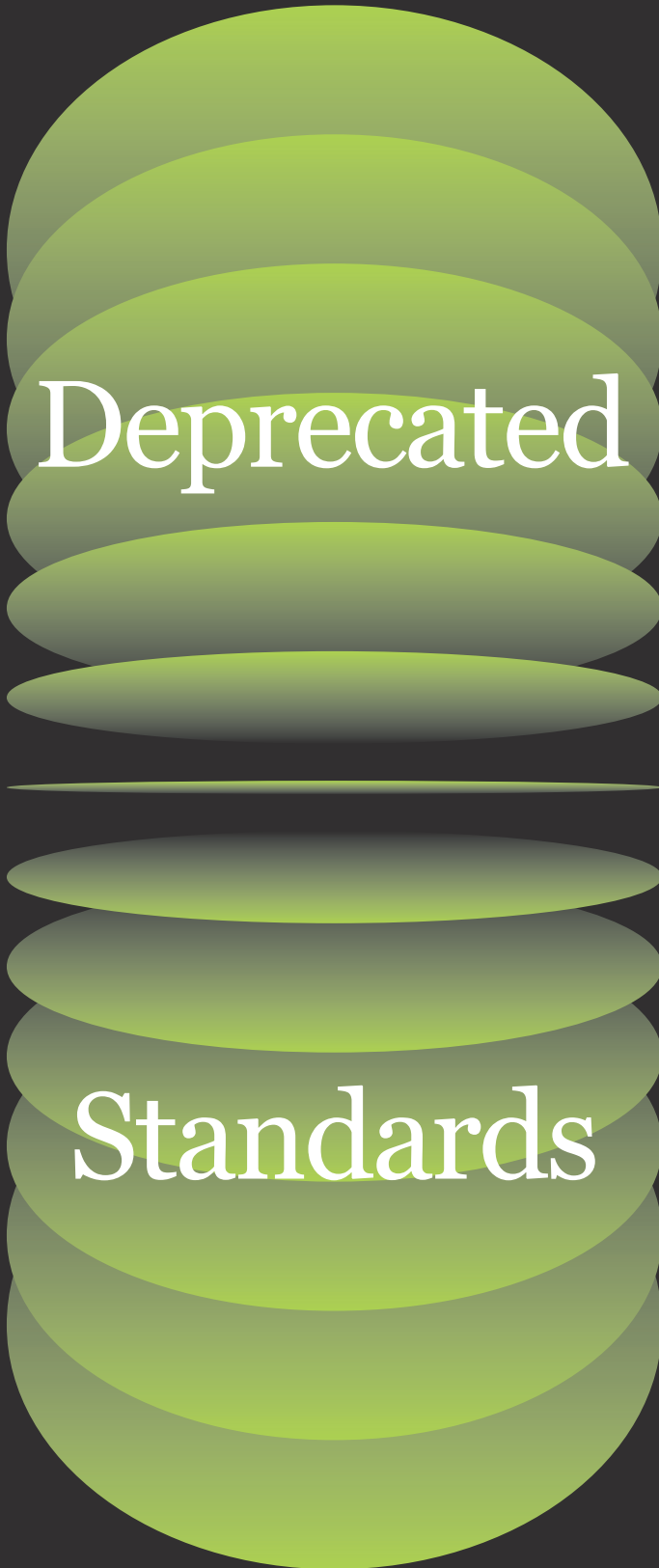
Adoption

All three standards confront similar obstacles limiting production deployment. Manufacturing integration costs (whether \$50 or \$0.50 per unit) create economic viability questions for all but premium goods. Production line modifications require capital investment and process redesign that brands resist without clear ROI. Consumer value propositions remain unclear beyond novelty, with users questioning what NFT ownership actually provides versus traditional proof of purchase. Web2 alternatives like QR codes

with centralized databases often suffice for authentication needs without blockchain complexity or chip integration.

The prescriptive spectrum differences reflect these realities. Standards addressing hardware integration maintain flexibility (52-72%) where rigid prescription would constrain innovation, unlike securities standards where comprehensive prescription (100%) builds institutional confidence through proven compliance architectures.

Dimension	Cryptographic (ERC-4519)	Simple Chip (ERC-5791)	Oracle (ERC-6956)
Hardware	Secure element (\$5-50)	NFC/RFID (\$0.10-1)	None (\$0)
Security	Unforgeable signatures	UID cloning possible	Trust required
Manufacturing	Complex integration	Moderate integration	No changes needed
Existing Assets	Cannot retrofit	Cannot retrofit	Works retroactively
Verification	Instant (scan)	Instant (scan)	Delayed (oracle)
Trust Model	Trustless	Trustless	Oracle dependency



Deprecated

Standards

Previous sections examined standards targeting specific asset classes, each optimized for particular tokenization scenarios. This section covers a different category: standards that were proposed, generated varying degrees of attention, and ultimately failed to achieve lasting adoption. Their trajectories provide instructive lessons about what the ecosystem needs versus what seems promising in theory.

The three standards in this section failed for distinct reasons revealing broader patterns. ERC-404 demonstrated that marketing hype cannot substitute for technical rigor, achieving viral attention in February 2024 before collapsing under extreme gas costs and security vulnerabilities. ERC-1400 showed how overcomplexity and single-company ownership can undermine even well-intentioned standards when sponsors pivot away. ERC-721 revealed that technically sound approaches fail when network effects favor alternatives and when a standard's design conflicts with how markets actually operate.

These experiments teach that successful standards solve specific problems well rather than attempting universal solutions, and that organic multi-implementer adoption proves more durable than single-entity design regardless of technical sophistication.

ERC-404: The Pandora Experiment

ERC-404 emerged in February 2024 as an attempt to combine ERC-20 and ERC-721 functionality in a single contract, enabling "fractional NFTs" where purchasing one full fungible token automatically minted a corresponding unique NFT. Developed by pseudonymous creators "ctrl" and "Acme," the Pandora project launched the concept and generated millions in trading volume within days, briefly reaching a market capitalization exceeding \$200 million. The PANDORA token surged approximately 12,000% in its first week as

copycat projects proliferated across Ethereum, Arbitrum, and Solana. Major platforms including OKX, Blur, and OpenSea announced integration support, further amplifying attention. Critically, ERC-404 was never submitted through official EIP processes. It existed only as a GitHub repository explicitly described as "experimental and unaudited," bypassing the community review and technical oversight that legitimate Ethereum standards require.

Status	Deprecated (never submitted as formal EIP)
Prescriptive Spectrum	N/A (not evaluated due to broken design)
Adoption	Abandoned (February 2024 hype cycle followed by collapse)
Best For	No legitimate use cases (failed experiment)

Why It Failed

The technical problems surfaced quickly once the initial excitement subsided. Executing both ERC-20 and ERC-721 logic simultaneously consumed 3-5 times normal gas, making ongoing trading prohibitively expensive and contributing to broader Ethereum network congestion during peak activity. Complex state synchronization between fungible and non-fungible representations created edge cases that developers publicly identified as potential exploit vectors, including token duplication risks and accounting inconsistencies in lending pools not configured for hybrid token behavior. Wallet interfaces designed for either fungible or NFT tokens could not properly display hybrid assets, creating persistent user confusion about what they actually held. The DN-404 standard emerged almost immediately as a community-driven alternative, explicitly asserting that ERC-404 "doesn't follow existing standards, is inefficient and breaks at certain edge cases." Within weeks, the ERC-404 sector lost approximately \$60-70 million in value in a single 24-hour period and trading volume across projects evaporated as developers published increasingly critical technical analyses.

Lessons Learned

Marketing alone cannot create legitimacy. Viral attention and exchange listings provide no substitute for the technical rigor that formal EIP processes enforce. ERC-1155 already addressed the multi-token problem that ERC-404 attempted to solve, combining fungible and non-fungible capabilities in a well-audited standard with broad ecosystem support. For asset tokenization, where real value is at stake, proven standards matter significantly more than experimental approaches. The ERC-404 episode also demonstrated the risks of bypassing standardization entirely, as the absence of community review meant design flaws that would have been caught during the EIP process instead resulted in real financial losses for users. The entire sector lost \$60-70 million in a single 24-hour period during the collapse, underscoring that novelty without rigor creates liabilities rather than innovation.

ERC-1400: The Polymath Standard

ERC-1400 was Polymath's comprehensive security token standard, proposed in September 2018 with the ambition of creating a unified framework for all security tokens on Ethereum. Rather than a single specification, ERC-1400 functioned as an umbrella encompassing four sub-standards: ERC-1410 (partially fungible tokens with partition management), ERC-1594 (core transfer restrictions and error signaling), ERC-1643 (document management), and ERC-1644 (controller operations including forced transfers).

The architecture introduced partition-based management allowing single contracts to handle multiple share classes with different rights, attempting to solve transfer restrictions, document management, forced transfers, issuance controls, and regulatory reporting simultaneously. Polymath positioned the standard as the foundation for its tokenization platform, with early adoption from organizations including ConsenSys and BNP Paribas.

Status	Stalled (never achieved Final, effectively deprecated)
Prescriptive Spectrum	N/A (comprehensive but incomplete specification)
Adoption	Historical only (legacy implementations remain, no new usage)
Best For	No current use cases (superseded by ERC-3643)

Why It Failed

The standard's ambition became its primary obstacle. Addressing transfer restrictions, document management, forced transfers, issuance controls, and regulatory reporting simultaneously made ERC-1400 difficult to implement correctly and even harder to audit for security. The specification encompassed four interconnected sub-standards (ERC-1410, 1594, 1643, 1644), each requiring correct implementation for the whole to function. Reliance on external verifiers for transfer authorization created centralization risks that undermined blockchain security guarantees. The specification was optimized for Polymath's platform architecture rather than general applicability, creating friction for external implementations. Most critically, ERC-1400 never achieved Final EIP status due to ongoing changes and unclear specifications, deterring adopters who needed stable foundations to build upon. When Polymath pivoted toward building Polymesh, a purpose-built permissioned blockchain for regulated assets, ERC-1400 lost its primary advocate and developer. This exposed the fragility of single-company standards. Without neutral governance or multi-firm stewardship, the standard had no sustainability mechanism beyond Polymath's continued commitment. The ConsenSys Universal Token implementation remains available but is no longer actively maintained. Legacy implementations represent technical debt rather

than active development, with no new projects choosing ERC-1400 over alternatives with broader ecosystem support.

Lessons Learned

Simplicity and focus prove more adoptable than attempting universal coverage. ERC-3643's focused architecture and modular compliance system achieved the institutional adoption that ERC-1400's comprehensive approach did not, despite ERC-1400 arriving first. Single-company standards create sustainability risk, as business model changes leave adopters with unsupported infrastructure that becomes technical debt. Multi-firm consortiums provide better long-term stewardship by distributing responsibility across organizations with aligned but independent incentives. The inability to complete standardization through Final EIP status signaled fundamental consensus issues that the market ultimately resolved by choosing alternatives. ERC-1400's legacy is not entirely negative, as concepts it introduced (partition management, document management, controller operations) influenced later standards. ERC-3643's dominance came partly from incorporating lessons that ERC-1400's experience revealed, including the importance of modular compliance, on-chain identity infrastructure, and recovery mechanisms.

ERC-721o: Opium Protocol Derivatives

ERC-721o was Opium Protocol's attempt to model derivatives as composable, multiclass NFTs. Designed by the Opium team led by Andrey Belyakov, a professional derivative trader with a decade of experience and CFA Institute membership, the standard extended ERC-721 with derivative-specific functionality. Each derivative contract was represented as a unique token containing terms, collateral references, and settlement conditions. The standard introduced portfolio composition and decomposition functions, allowing users to bundle multiple derivative positions into a single token for

management and trading. A "compose" function merged individual derivative tokens into portfolio tokens, while "decompose" broke portfolios back into constituents. The approach treated every option, swap, or forward as a unique instrument with its own tokenId, combining elements of ERC-20 and ERC-721 to create what the team described as a "composable multiclass fungible token standard" for financial instruments. The team drew inspiration from how traditional exchanges manage derivative portfolios, translating the concept of combined orders and portfolio margin into token primitives.

Status	Deprecated (no formal EIP submission)
Prescriptive Spectrum	N/A (specialized NFT-based approach)
Adoption	None (confined to Opium Protocol platform)
Best For	No current use cases (superseded by general derivative frameworks)

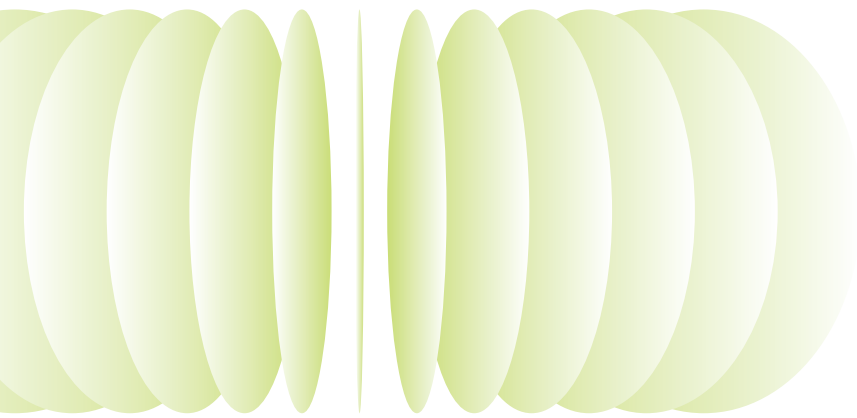
Why It Failed

The fundamental design choice of representing derivatives as unique NFTs conflicted with how derivatives markets actually operate. Traditional derivatives achieve efficiency through standardization, where all options with identical parameters trade as fungible instruments creating deep liquidity pools. ERC-721o's uniqueness created perpetual liquidity fragmentation, as each derivative being a distinct NFT prevented the natural fungibility that traders and market makers require for efficient price discovery. Managing NFT collections for derivative positions felt unnatural to traders accustomed to order books and fungible positions.

As institutional attention shifted toward standards like ERC-6123 (smart derivative contracts designed by quantitative finance experts with formal state-machine lifecycle management) and general derivative frameworks, the NFT-based approach appeared increasingly niche. ERC-721o's association with a single platform prevented ecosystem-wide consideration, and the standard was never submitted through the formal EIP process.

Lessons Learned

Technical elegance does not ensure adoption. While conceptually interesting and developed by genuine domain experts in quantitative finance, the NFT model failed to address the practical requirements of derivatives traders for fungibility, liquidity, and familiar interfaces. Network effects matter enormously in derivatives markets, where critical mass is required for efficient price discovery and thin liquidity creates adverse selection that drives participants away. General standards that accommodate diverse derivative types through parameterization while maintaining fungibility where appropriate have attracted more institutional attention than specialized token representations. The ERC-721o experience also reinforces a recurring theme across deprecated standards: matching technology to actual market needs proves more important than forcing assets into particular token primitives based on architectural analogies. The world's largest financial market required an approach that prioritized how traders actually operate over how elegantly derivatives could be represented on-chain.



Patterns in Deprecated Standards

The three deprecated standards share common failure patterns despite addressing different asset classes and use cases. Each prioritized technical innovation over market alignment, and each suffered from insufficient community governance.

ERC-404 failed fastest, lasting only weeks from peak hype to abandonment. Its collapse was driven by fundamental technical flaws that formal EIP review would have identified before deployment. The absence of standardization processes meant users bore the cost of discovering design failures in production. ERC-1400 persisted longer (2018-2022) but ultimately stalled when its sole corporate sponsor pivoted away, demonstrating the fragility of standards tied to individual companies. ERC-721o never achieved meaningful attention outside its originating platform, illustrating that single-entity development without community adoption produces technically interesting proposals that remain permanently niche.

Key Points

The successful standards examined in earlier sections share characteristics these deprecated standards lacked. Community-driven governance through multi-firm consortiums provides sustainability beyond any single company's commitment. Formal EIP processes catch design flaws before they cause production losses. Focused

scope addressing specific problems well proves more adoptable than attempting comprehensive universal solutions. And alignment with actual market behavior, rather than theoretical elegance, determines whether a standard attracts the sustained adoption needed to become industry infrastructure.

Dimension	ERC-404	ERC-1400	ERC-721 0
Active Period	Weeks (Feb 2024)	~4 years (2018-2022)	Limited (single platform)
Primary Failure	Technical flaws	Corporate abandonment	Market misalignment
EIP Submission	Never submitted	Draft (never Final)	Never submitted
Peak Adoption	Millions in volume	ConsenSys, BNP Paribas	Opium Protocol only
Superseded By	ERC-1155	ERC-3643	ERC-6123, general frameworks



The Foundation is Laid

The early stages of asset tokenization have established critical infrastructure within the Ethereum ecosystem. This report examined 25+ Ethereum Improvement Proposals across seven categories, from securities compliance to physical asset linking, from tokenized vaults to profit distribution mechanisms.

Clear leaders have emerged. ERC-3643 dominates securities tokenization with \$28-32B in cumulative managed assets, 100+ institutional association members, and regulatory engagement across ESMA, MAS, and the SEC Crypto Task Force. ERC-4626 powers \$1.68B+ in vault TVL and has become the composability standard for yield-bearing tokens across DeFi and increasingly TradFi applications. The foundational standards (ERC-20, ERC-721, ERC-1155) provide the bedrock upon which all specialized standards build.

Other categories show varying maturity. Physical asset standards remain experimental, facing compounding barriers in infrastructure costs, manufacturing integration, and consumer adoption. Bond and derivative standards exist in specification but lack

production usage, constrained by oracle dependencies, regulatory uncertainty, and the systemic coordination required to bring trillion-dollar instrument markets on-chain. Newer entrants like ERC-7943 and ERC-7518 introduce different architectural approaches to securities compliance but remain too early to evaluate against production metrics.

The foundation is real. But selectivity matters. Most proposed standards do not achieve adoption, and choosing the wrong one carries significant cost in development resources, regulatory positioning, and opportunity.

Why standards emerged on open networks: Ethereum's permissionless architecture, where anyone can deploy smart contracts, creates coordination challenges that closed platforms avoid. Without agreed standards, tokens become incompatible, platforms cannot integrate diverse assets, and the ecosystem fragments into siloed implementations. Standards enable the interoperability that transforms isolated experiments into composable infrastructure.

What Works

Characteristics of Standards That Achieved Adoption

- **Production usage at scale.** Billions in assets or TVL validate real solutions. Theoretical implementations, regardless of technical merit, don't demonstrate market readiness as clearly as production implementations.
- **Institutional backing.** Major firms using or supporting the standard create network effects that compound with scale. ERC-3643's 100+ member association and ERC-4626's integration across leading DeFi protocols illustrate this pattern.
- **Regulatory recognition.** Mention in official regulatory documents (ESMA DLT Pilot Regime reports, MAS Project Guardian frameworks, SEC Crypto Task Force engagement) signals credibility and reduces adoption risk for institutions.
- **Final EIP status.** Completing Ethereum's multi-year standardization process demonstrates technical consensus and community validation. Years of review filter design flaws before they reach production.
- **Mature ecosystem.** Comprehensive tooling, documentation, security audits, and active developer communities provide the infrastructure that implementation teams require.
- **Clear value proposition.** Successful standards solve a specific problem better than alternatives. The answer to "why this standard?" is immediately apparent from the use case.
- **Appropriate complexity.** Neither oversimplified nor overcomplicated for the target use case. The right level of prescription for the problem domain.

What Fails

Characteristics of Standards That Did Not Achieve Adoption

- **No production usage despite time in market.** Standards that remain theoretical years after proposal indicate the market has not validated the approach.
- **Overcomplexity without corresponding benefits.** High implementation barriers that do not deliver proportional value deter adoption. Sophistication without users remains academic.
- **Creator abandonment.** When even the proposing team moves on to different approaches, as Polymath did with ERC-1400, the standard loses its primary advocate and development momentum.
- **Poor timing.** Arriving too early (before market readiness) or too late (after alternatives become entrenched) closes the adoption window. Network effects narrow the window for competing standards over time.
- **Single-company dependency.** Standards tied to a single entity's commercial interests lack ecosystem resilience if that company pivots, restructures, or deprioritizes the standard.
- **Fundamental technical limitations.** Excessive gas costs, security vulnerabilities, or architectural constraints that cannot be resolved through iteration. ERC-404's 3-5x gas overhead exemplifies this pattern.

Critical Trade-offs Revealed

Three fundamental tensions recur across the standards landscape. Each reveals how markets resolve competing design philosophies.

Comprehensive vs. Simple

ERC-3643's multi-layer architecture (ONCHAINID identity management, modular compliance modules, claim registries, recovery mechanisms) sits at one end of the spectrum. ERC-1404's two-function interface (`detectTransferRestriction`, `messageForTransferRestriction`) sits at the other. The market resolved this tension through segmentation. Comprehensive prescription proved necessary for complex use cases requiring KYC, accreditation verification, and multi-jurisdictional compliance. Simple interfaces proved sufficient for basic needs like whitelist-only restrictions. The practical lesson is that appropriate complexity varies by category, and the market has demonstrated a strong preference for comprehensive approaches when institutional capital and regulatory compliance are at stake.

Standards vs. Frameworks

Prescriptive standards provide complete, ready-to-

deploy solutions. Flexible frameworks enable customization but leave implementation decisions to adopters. For critical infrastructure requiring regulatory compliance, the market has overwhelmingly preferred prescription over flexibility. For example, ERC-3643 dominates while framework approaches remain confined to niche applications. This pattern is consistent with how traditional financial infrastructure evolved, where standardization enabled scale and interoperability. However, the emergence of newer lightweight standards like ERC-7943 with coalition backing suggests the market continues to explore whether minimal interfaces can achieve comparable ecosystem effects through a different path. This question remains open.

Early Mover vs. Better Execution

ERC-1404 was proposed in September 2018 with SEC filing validation. ERC-3643 arrived nearly three years later in July 2021 with a comprehensive architecture and institutional ecosystem strategy. Despite ERC-1404's head start, ERC-3643 achieved the dominant market position through superior execution, ecosystem building, and institutional engagement. The same pattern appears

in other categories. ERC-1400's 2018 proposal preceded ERC-3643 and offered a more comprehensive vision than ERC-1404, yet neither early entrant captured the market that a later, better-executed standard claimed.

First-mover advantage in standards is less determinative than quality of execution, ecosystem development, and institutional confidence.

Final Reflection

The Ethereum RWA tokenization landscape is no longer speculative. Real assets, \$28-32B in securities and \$1.68B+ in vaults, operate on-chain today using standards analyzed in this report. Clear leaders have emerged in critical categories. Infrastructure exists for institutional deployment.

But selectivity remains essential. Most proposed standards do not achieve adoption. Complexity without production validation limits momentum. The history of Draft-status proposals that never progressed serves as a consistent reminder that technical merit alone does not guarantee market success.

The question is no longer whether asset tokenization will happen. It is how, when, and which standards will power the infrastructure. This report provides the analytical foundation to inform those decisions.





The Institutional
Guide to Ethereum
RWA Token Standards