The Tokenization Revolution: When Every Asset Becomes Digital

Module 6: The Infrastructure Problem

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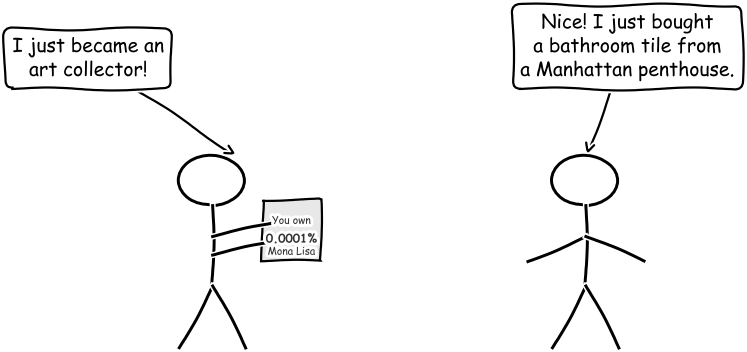
Digital Finance — BSc Course

Tokenization is transforming capital markets — turning illiquid, exclusive assets into programmable, tradeable digital tokens.

The Fractional Future



FRACTIONAL EVERYTHING

The tokenization revolution, one ten-thousandth at a time.

"I own 0.003% of a Picasso, 0.0001% of a skyscraper, and 100% of my student debt." — Fractional ownership changes who can invest, not what they earn.

Learning Objectives

After completing this lecture, you will be able to:

1. **Define** tokenization and distinguish it from mere digitization [Understand]
2. **Explain** five key benefits of tokenized assets: fractional ownership, 24/7 trading, instant settlement, programmable compliance, and global access [Understand]
3. **Compare** token standards (ERC-20, ERC-721, ERC-1400) and their suitability for different asset classes [Analyze]
4. **Evaluate** institutional case studies — BlackRock BUIDL, SDX, JPMorgan Onyx, Franklin Templeton — and their strategic rationale [Evaluate]
5. **Assess** regulatory frameworks (Swiss DLT Act, EU pilot regime, US landscape) and residual risks [Evaluate]

Bloom's levels covered: Understand, Analyze, Evaluate

Objectives follow Bloom's taxonomy: Understand → Analyze → Evaluate.

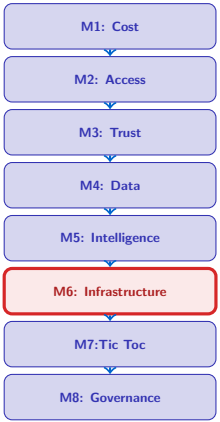
Bridge: From Trust to Tokenization

Module 3 showed us that blockchains solve the trust problem — strangers can transact without intermediaries.

Module 6 asks: *what happens when we rebuild financial infrastructure on top of that trust layer?*

This lecture tackles the most radical implication:

- If blockchains can record ownership trustlessly...
- ...then **any asset** can become a digital token
- Real estate, bonds, private equity, art — all tradeable like stocks



This lecture

Tokenization sits at the intersection of trust infrastructure (M3) and financial plumbing (M6) — it is where blockchains meet real-world assets.

The Central Question

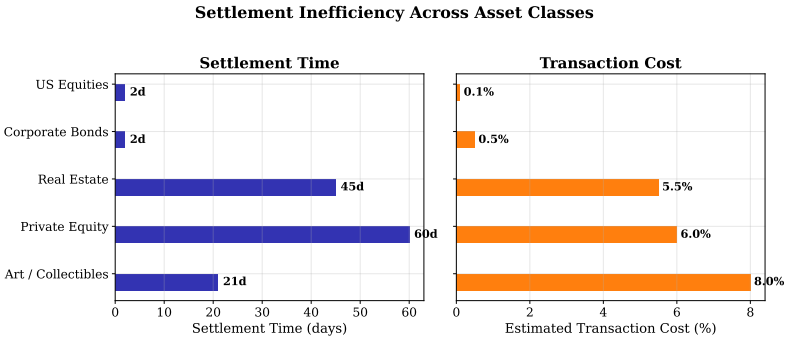
"What if every asset in the world were as easy to buy as a stock?"

Three guiding sub-questions:

1. Which assets benefit **most** from tokenization — and which gain little?
2. What **infrastructure** must exist before tokenized markets can scale?
3. What new **risks** emerge when real-world assets live on a blockchain?

These three questions structure the entire lecture — we return to each in the summary.

The $300 Trillion Problem



Illustrative estimates | Sources: DTCC, industry reports

What you see: The total value of major asset classes — global real estate ($326T), bonds ($130T), equities ($109T), private equity ($8T), art and collectibles ($68B) — alongside the fraction that is easily tradeable. **Key pattern:** The largest asset classes are the least liquid. **Takeaway:** Over $300 trillion in assets suffers from high transaction costs, limited trading hours, and minimum investment barriers.

Most of the world's wealth is locked in illiquid assets — Sources: Savills Global Real Estate 2024, BIS Quarterly Review 2024, Bain PE Report 2024.

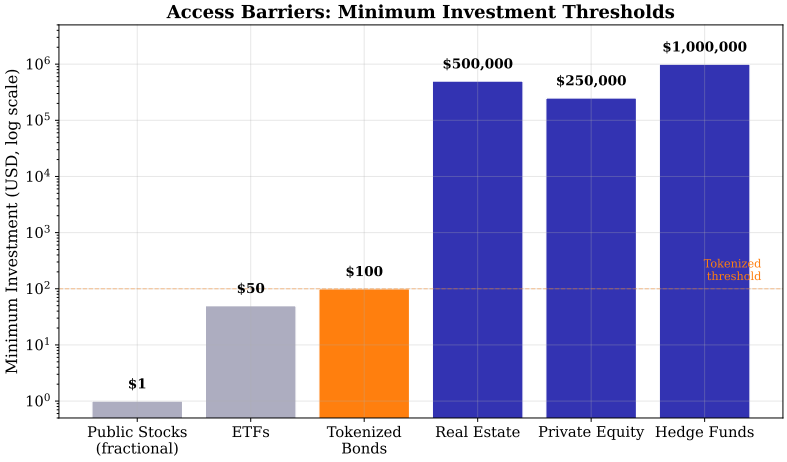
A Tale of Two Trades

Buying Apple Stock	Buying Bitcoin
Market hours: 9:30–16:00 EST only	Market hours: 24/7/365
Settlement: T+1 (was T+2 until May 2024)	Settlement: T+0 (minutes)
Minimum: 1 share (~$170)	Minimum: 1 satoshi ($0.0006)
Access: Brokerage account required	Access: Internet connection
Intermediaries: Broker, DTCC, custodian	Intermediaries: None (self-custody)

Paradox: The 50-year-old market is slower than the 15-year-old one.
Why can't stocks work like Bitcoin?

Tokenization asks: can we give traditional assets the trading properties of crypto — 24/7, instant, fractional, global — while keeping the legal protections?

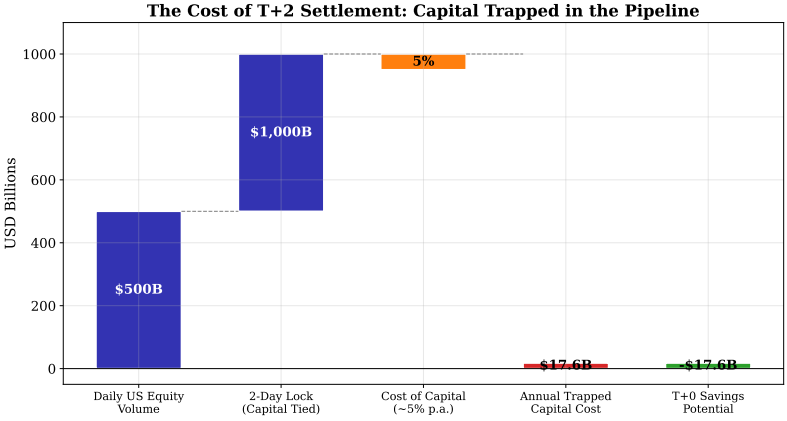
Who Gets Left Out?



Tokenization dramatically lowers entry barriers

What you see: Minimum investment thresholds across asset classes — venture capital ($250K+), private equity ($100K+), commercial real estate ($50K+), hedge funds ($1M+). **Key pattern:** The highest-returning assets have the highest entry barriers. **Takeaway:** Roughly 95% of the global population is locked out of institutional-grade investments by minimum ticket sizes alone.

The Settlement Tax



Illustrative estimates | Instant settlement could unlock ~$17.6B annually

What you see: The cost of delayed settlement across markets — US equities (T+1), European bonds (T+2), syndicated loans (T+10–20), real estate (T+30–90). **Key pattern:** Longer settlement = more trapped capital = higher cost. **Takeaway:** An estimated $17.6 billion per year is lost to capital trapped during settlement delays (illustrative, based on industry estimates).

Settlement delay is a hidden tax on every trade — capital locked during T+1 or T+2 could be deployed elsewhere.

What If We Could Fix All of This?

Tokenization addresses five market failures simultaneously:

1. **Fractional ownership** — A $500,000 property becomes 10,000 tokens at $50 each. Anyone can invest.
2. **24/7 trading** — No market close, no weekends. A bond token trades at 3:00 AM on a Sunday.
3. **Instant settlement** — Delivery-versus-payment in seconds, not days. No counterparty risk window.
4. **Programmable compliance** — Know-Your-Customer (KYC) and Anti-Money-Laundering (AML) rules baked into the token. The token itself enforces who can hold it.
5. **Global access** — A farmer in Kenya and a pension fund in Zurich trade the same instrument on the same ledger.

These five benefits are not independent — they compound. Fractional + 24/7 + instant settlement creates entirely new market dynamics.

Think-Pair-Share: Your Most Illiquid Asset

Activity (3 minutes)

1. **Think** (1 min): What is the most valuable asset you or your family owns that would be **hard to sell quickly**? (Examples: a house, a car, a family business, collectibles, land)
2. **Pair** (1 min): Tell your neighbor: *How long would it take to sell? What percentage would you lose to fees?*
3. **Share** (1 min): Would tokenizing that asset help? What would change — and what would stay the same?

Key insight: Most people's largest asset (their home) is also their most illiquid. Tokenization could change that — but only if the infrastructure exists to support it.

Engagement exercise — helps students connect the abstract concept of tokenization to assets they personally understand.

What Is Tokenization?

Definition: Tokenization

Tokenization is the process of representing ownership rights to a real-world asset as a digital token on a distributed ledger (blockchain). Each token is a programmable, transferable record of a legal claim.

Tokenization does not move the painting — it creates a digital twin of the ownership right. The painting stays in a vault; the claim moves on-chain.

Tokenization vs Digitization

Digitization

Converting information from physical to digital format.

- A PDF of a property deed
- A database entry at a bank
- An electronic stock certificate

Limitations:

- Still requires intermediaries to transfer
- Cannot be subdivided programmatically
- No built-in compliance or settlement logic
- Copy-paste problem: who holds the "real" version?

Tokenization

Creating a programmable, tradeable ownership claim on a blockchain.

- A token representing fractional ownership
- Ownership recorded on an immutable ledger
- Transfer rules encoded in the token contract

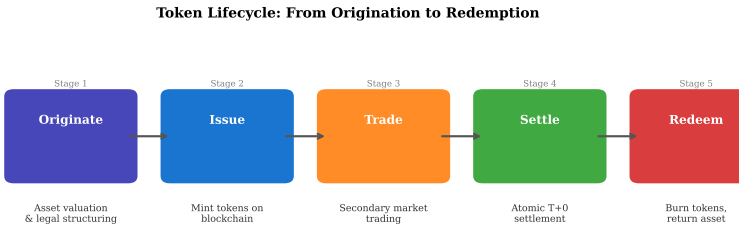
Advantages:

- Peer-to-peer transfer without intermediary
- Divisible to arbitrary precision
- Compliance logic executes automatically
- Single source of truth: the blockchain

Key insight: Digitization puts a document on a screen. Tokenization puts a *right* on a ledger.

This distinction matters: most financial "digitization" to date has moved paper to PDFs without changing the underlying ownership infrastructure.

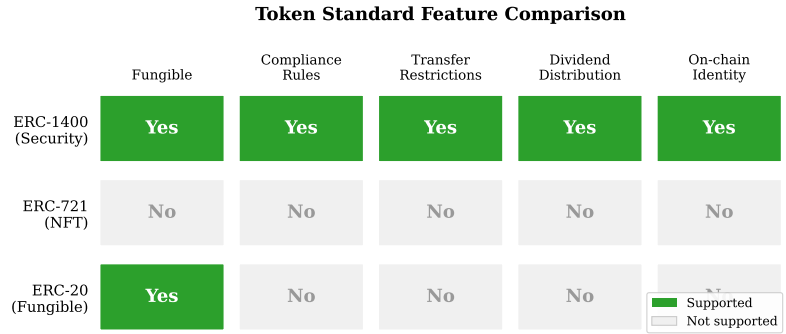
The Token Lifecycle



What you see: The five stages of a tokenized asset's life — (1) Originate: legal structuring and asset verification, (2) Issue: minting tokens on-chain, (3) Trade: secondary market exchange, (4) Settle: atomic delivery-versus-payment, (5) Redeem: burning tokens when the underlying asset is liquidated. **Key pattern:** Each stage maps to a traditional capital-markets function, but executed on-chain. **Takeaway:** Tokenization is not just issuance — the full lifecycle must work for markets to function.

Most tokenization pilots focus on issuance (stage 2) but struggle with trading and redemption (stages 3–5) — the "last mile" problem.

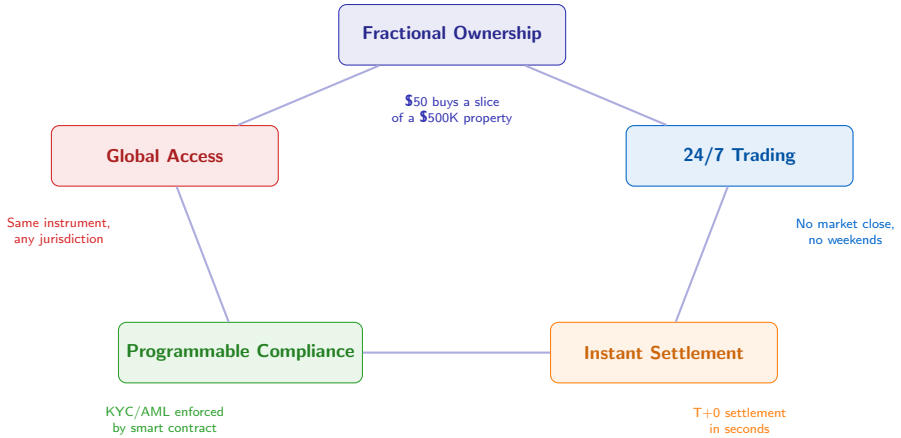
Token Standards Compared



What you see: Three Ethereum token standards side by side — ERC-20 (fungible tokens: every unit identical, like cash), ERC-721 (Non-Fungible Tokens (NFTs): each unit unique, like a deed), and ERC-1400 (security tokens: fungible but with built-in compliance controls such as transfer restrictions, forced transfers, and document management). **Key pattern:** ERC-1400 extends ERC-20 with regulatory features. **Takeaway:** Regulated asset tokenization requires ERC-1400 or equivalent — vanilla ERC-20 lacks compliance hooks.

ERC = Ethereum Request for Comments. ERC-1400 was proposed by Polymath in 2018 specifically for security tokens.

The Five Benefits of Tokenization



These five benefits form a reinforcing system — fractional ownership without global access limits the buyer pool; instant settlement without compliance creates regulatory risk.

Worked Example: Settlement Savings

Question: How much capital is trapped by settlement delays in US equity markets?

Calculation

Step 1: Average daily US equity trading volume $\approx$ \$500 billion

Step 2: Under T+1 settlement, one day's volume is locked at any time:
Trapped capital = \$500B $\times$ 1 = \$500B

Step 3: Opportunity cost at 5% annual cost of capital:
Daily cost = \$500B $\times \frac{0.05}{365}$ = \$68.5M per day

Step 4: Annual cost of trapped capital:
\$68.5M $\times$ 252 trading days = \$17.3B per year

Step 5: Under T+0 (tokenized settlement): trapped capital = \$0
Annual savings: ~\$17 billion (Source: order-of-magnitude model based on DTCC T+1 industry studies)

Note: Real savings depend on netting, margin offsets, and whether all trades move to T+0. Figures are illustrative.

Even partial adoption of T+0 settlement would free billions in trapped capital — this is why institutions like DTCC and JPMorgan are investing in tokenized settlement.

Worked Example: Fractional Real Estate

Question: What yield does a fractional real estate token deliver?

Calculation

Given:

Property value: $500,000 — Tokenized into: 10,000 tokens at $50 each
Annual net rent (after expenses): $36,000

Step 1: Rent per token $= \frac{\$36{,}000}{10{,}000} = \$3.60$ per token per year

Step 2: Token yield $= \frac{\$3.60}{\$50} = 7.2\%$ annual yield

Comparison:

Typical Real Estate Investment Trust (REIT) yield: ˜4%
Direct property ownership: ˜6–8%
Tokenized fraction: 7.2% (similar to direct, minus platform fees)

Caveat: Token yield assumes no platform fee, no liquidity discount, and stable occupancy. Real yields will be lower.

Fractional tokens can deliver near-direct-ownership yields while lowering the entry barrier from $500K to $50 — but fees and liquidity discounts matter.

The Custodial Question

"Who holds the painting when you own 50 tokens?"

Self-Custody

Token holder controls private key

Risk: Key loss = asset loss

Example: Self-hosted wallet

Qualified Custodian

Regulated institution holds keys

Risk: Counterparty risk returns

Example: Coinbase Custody

Hybrid

Multi-signature: investor + custodian

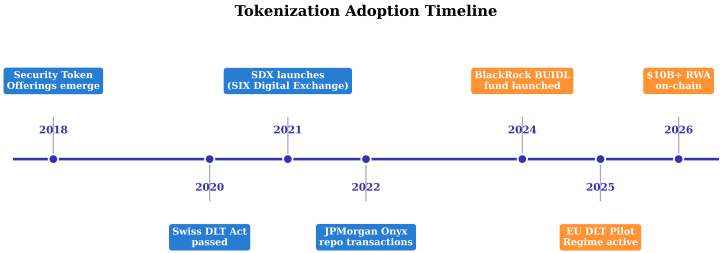
Risk: Coordination overhead

Example: Fireblocks MPC

Key insight: Custody is the unsolved problem of tokenization. Self-custody eliminates intermediaries but introduces key-management risk. Qualified custody reintroduces the intermediary that tokenization was supposed to remove.

MPC = Multi-Party Computation — a cryptographic technique where multiple parties jointly control a key without any single party knowing the full key.

The Institutional Adoption Wave



Key milestones in the evolution of asset tokenization

What you see: A timeline of institutional tokenization milestones — 2020: early experiments (SIX Digital Exchange launches), 2021–2022: pilot bond issuances (EIB digital bond), 2023: regulated platforms go live (SDX, JPMorgan Onyx), 2024: mainstream products (BlackRock BUIDL, Franklin Templeton on-chain fund), 2025–2026: scaling phase. **Key pattern:** Adoption accelerated sharply after 2023 as regulation caught up. **Takeaway:** We are exiting the pilot phase and entering the scaling phase.

Institutional adoption follows a pattern: internal experiment → regulated pilot → live product → scale. Most firms are now between stages 3 and 4.

Case Study: BlackRock BUIDL

BlackRock USD Institutional Digital Liquidity Fund (BUIDL)

- **Launched:** March 2024
- **AUM:** $500M+ within 6 weeks (as of mid-2024)
- **Blockchain:** Ethereum (public mainnet)
- **Structure:** Each token = $1, backed 1:1 by US Treasuries
- **Yield:** Daily accrual, distributed monthly
- **Redemption:** Instant 24/7 via USDC (a USD-pegged stablecoin)
- **Partner:** Securitize (tokenization platform)
- **Custodian:** Bank of New York Mellon

Why It Matters

BlackRock manages $10+ trillion. When the world's largest asset manager puts a product on Ethereum, it is not an experiment — it is a strategic bet that tokenized infrastructure is the future of fund management.

Student question:
Why would BlackRock use a *public* blockchain instead of building a private one?

BUIDL is significant not for its size but for its signal: the largest asset manager chose public Ethereum over private infrastructure. Source: BlackRock press release March 2024.

Why BlackRock Chose Blockchain

Dimension	Traditional Fund	BUIDL (Tokenized)
Trading hours	9:00–17:00 Mon–Fri	24 hours 7 days a week
Settlement	T+1 to T+3	T+0 (seconds)
Minimum invest.	$100,000 typical	$5M (institutional), but fractional
Redemption	End-of-day NAV	Instant via USDC
Record-keeping	Fund administrator	Ethereum blockchain

Key insight: BUIDL is not a different product — it is the *same product* (US Treasuries) delivered on better infrastructure. The asset did not change; the plumbing did.

BlackRock CEO Larry Fink: "Every asset can be tokenized, and if you tokenize it, it can democratize access to investments." (BlackRock Annual Letter 2024)

Case Study: SDX — Swiss Digital Exchange

SIX Digital Exchange (SDX)

- **Operator:** SIX Group (runs the Swiss Stock Exchange)
- **Launched:** November 2021 (FINMA-authorized)
- **Technology:** R3 Corda (permissioned distributed ledger)
- **Scope:** Issuance, trading, settlement, and custody of digital securities
- **Milestones:**
  - First digital bond: CHF 150M (Canton of Zurich, 2023)
  - First structured product: UBS digital bond
  - World Bank digital bond (CHF 200M, 2024)
- **Settlement:** Delivery-versus-payment (DvP) using a wholesale Central Bank Digital Currency (wCBDC) from the Swiss National Bank (Project Helvetia)

Why SDX Matters

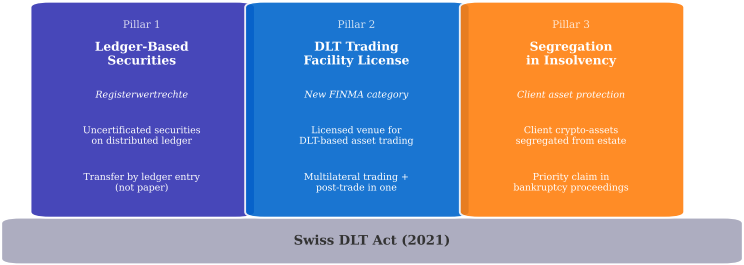
SDX is the first fully regulated, end-to-end digital exchange operated by a traditional stock exchange. It proves tokenized securities can work within existing regulatory frameworks — not around them.

Note: SDX chose a permissioned ledger, unlike BlackRock's public Ethereum approach. Both are valid — the tradeoff is openness vs. control.

SDX settlement uses real Swiss franc CBDC (Project Helvetia Phase III) — making it the first exchange to settle digital securities with central bank money. Source: SIX press releases 2023–2024.

The Swiss DLT Act

Three Pillars of the Swiss DLT Act



Enacted 2021 | One of the first comprehensive blockchain legal frameworks globally

What you see: The three pillars of Switzerland's DLT Act (effective August 2021) — (1) Registerwertrechte ("register-based securities"): a new legal category allowing digital tokens to carry the same legal weight as traditional securities, (2) DLT trading facility license: a new authorization category for exchanges that trade tokenized assets, (3) Segregation in insolvency: digital assets are separated from the estate of a failed custodian, protecting token holders. **Key pattern:** Switzerland adapted existing law rather than creating a separate "crypto law." **Takeaway:** The DLT Act is considered the global gold standard for tokenization regulation.

DLT = Distributed Ledger Technology. The Swiss approach: technology-neutral, principle-based, integrated into existing financial law. Source: Swiss Federal Council DLT Dispatch 2020.

Case Study: JPMorgan Onyx

JPMorgan Onyx Platform

- **Launched:** 2020 (evolved from JPM Coin, 2019)
- **Scale:** $700B+ processed in intraday repo transactions (as of 2024)
- **Products:**
  - **JPM Coin:** internal USD token for wholesale payments
  - **Tokenized Collateral Network (TCN):** tokenized money market fund shares used as margin collateral
  - **Kinexys (formerly Onyx):** rebranded platform for institutional DLT services
- **Use case:** Intraday repo — borrowing cash for hours, not days, using tokenized collateral

Why Onyx Matters

JPMorgan is not tokenizing for ideology — it is tokenizing for **efficiency**. Intraday repo with tokenized collateral eliminates overnight funding costs and frees trapped capital.

Key insight: JPMorgan's approach shows tokenization's value in *institutional plumbing* — not retail democratization, but back-office cost reduction.

Onyx processed $700B+ in intraday repo by 2024, making it the largest live tokenization deployment by transaction volume. Source: JPMorgan Onyx press materials 2024.

Case Study: Franklin Templeton On-Chain Fund

Franklin OnChain US Government Money Fund

- **Launched:** April 2023 (first US-registered fund on-chain)
- **Blockchains:** Stellar and Polygon
- **Structure:** Each token = 1 fund share, backed by US Treasuries and repos
- **AUM:** $400M+ (as of early 2025)
- **Innovation:** Fund shares recorded on a public blockchain, not just a traditional transfer agent
- **Transfers:** Peer-to-peer between approved wallets
- **Regulator:** SEC-registered under the Investment Company Act

The Significance

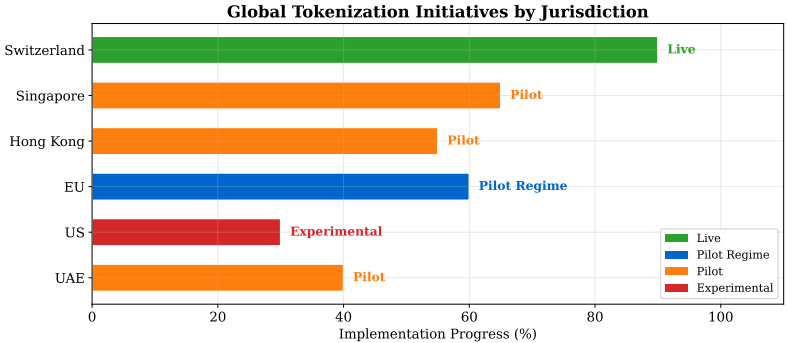
Franklin Templeton proved you can operate a fully SEC-compliant fund on a public blockchain. The legal structure is identical to a traditional money market fund — only the record-keeping layer changed.

Distinction: Unlike BlackRock BUIDL (Ethereum-only, institutional), Franklin Templeton uses multiple chains and targets a broader investor base.

Franklin Templeton manages $1.5T+ in total assets. Their on-chain fund is evidence that tokenization is compatible with existing securities regulation.

Source: Franklin Templeton press release 2023.

Global Pilots and Initiatives

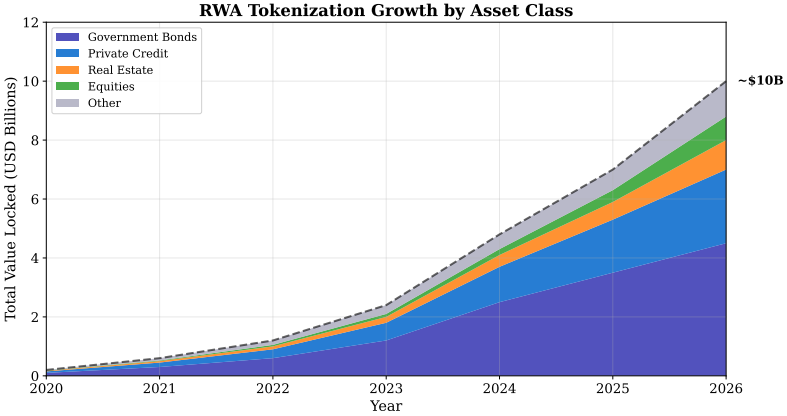


Progress estimates are illustrative | As of 2025

What you see: A map of major tokenization initiatives worldwide — MAS Project Guardian (Singapore: tokenized bonds, FX, asset management with industry partners), Hong Kong tokenized green bonds (HKMA: HK$800M digital green bond, 2023), EU DLT Pilot Regime (effective March 2023: sandbox for tokenized securities trading), UK FCA Digital Securities Sandbox, and Dubai DIFC tokenized sukuk. **Key pattern:** Every major financial centre is running at least one tokenization pilot. **Takeaway:** Tokenization is not a fringe experiment — it is a global regulatory and institutional movement.

MAS = Monetary Authority of Singapore. HKMA = Hong Kong Monetary Authority. DIFC = Dubai International Financial Centre. Sources: respective authority publications 2023–2024.

Real World Assets On-Chain: Growth Trajectory

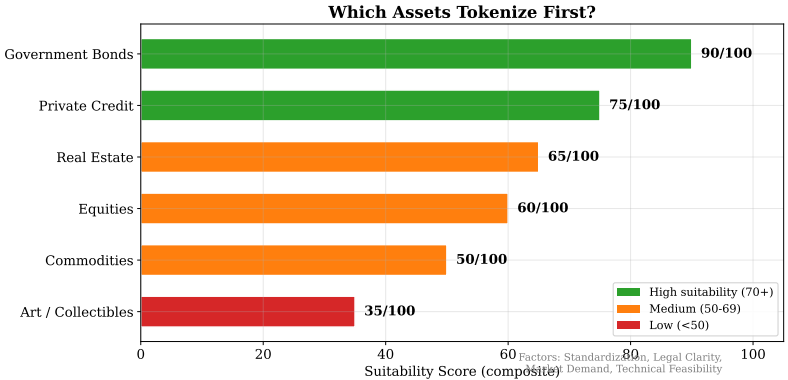


Illustrative estimates based on industry reports (DefiLlama, rwa.xyz, BCG)

What you see: Growth of tokenized Real World Assets (RWAs) on public blockchains, excluding stablecoins — from approximately $1B in early 2022 to ~$15–25B (*rwa.xyz tokenized RWA tracker*, April 2026). **Key pattern:** Growth accelerated sharply in 2024–2025, driven by tokenized US Treasuries (BlackRock BUIDL, Franklin Templeton BENJI, Ondo Finance). **Takeaway:** RWA tokenization is the fastest-growing segment in blockchain, but $15–25B is still a rounding error against the $300T+ illiquid-asset universe it aspires to digitise.

RWA = Real World Asset. Data excludes stablecoins (which are themselves tokenized dollars). Sources: rwa.xyz tokenized RWA tracker, DefiLlama, on-chain data 2022–2026.

What Gets Tokenized First?



Composite scores are illustrative | Based on standardization, legal clarity, demand, feasibility

What you see: A ranking of asset classes by tokenization readiness, based on standardization, regulatory clarity, and custody simplicity — government bonds (highest: standardized, clear regulation, digital-native custody), private credit (high: illiquid market benefits most), real estate (medium: complex legal frameworks, jurisdiction-dependent), equities (lower: already liquid, less marginal benefit), art and collectibles (lowest: valuation subjective, provenance complex). **Key pattern:** The first assets tokenized are those with the simplest legal wrappers, not the ones with the greatest retail appeal. **Takeaway:** Government bonds lead because they are boring — and boring is easy to regulate.

This ranking explains why BlackRock and Franklin Templeton started with Treasuries, not real estate or equities. Simplicity first, complexity later.

Discussion: Would You Buy a Tokenized Bond?

Scenario

A Swiss cantonal bond is available in two formats:

- **Traditional:** CHF 5,000 minimum, T+2 settlement, trades on SIX during market hours
- **Tokenized:** CHF 100 minimum, T+0 settlement, trades 24/7 on SDX

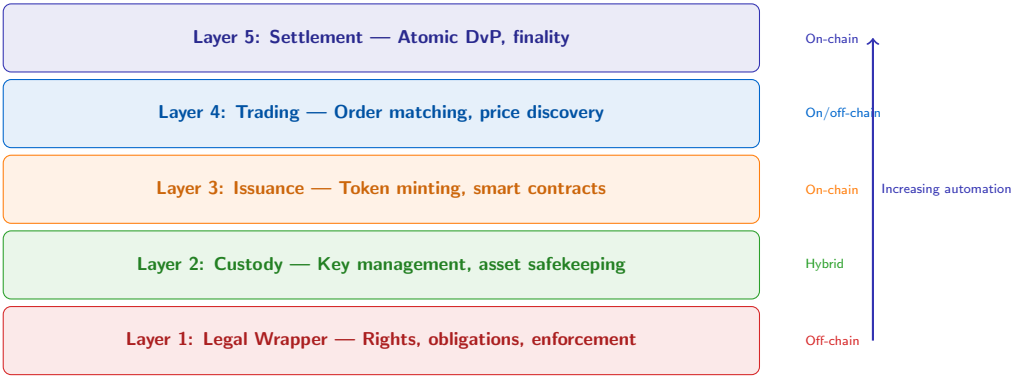
Same issuer, same coupon, same credit risk. The only difference is the infrastructure.

Discussion questions (3 minutes):

1. Which would you choose? Why?
2. What additional information would you need before deciding?
3. If both formats exist simultaneously, what happens to the price difference?
4. Does the "same issuer, same coupon" claim hold if the legal wrapper is different?

This scenario is real: the Canton of Zurich issued a CHF 150M digital bond on SDX in 2023, alongside its traditional bond program. Source: SDX press release November 2023.

The Tokenization Stack



Key insight: The stack moves from fully off-chain (legal) to fully on-chain (settlement). The hard problems live at the boundaries — where legal rights meet code.

A tokenized asset is only as strong as its weakest layer. Most failures occur at Layer 1 (legal wrapper) or Layer 2 (custody), not at the blockchain level.

Layer 1: The Legal Wrapper

The token is NOT the asset.

The token represents a **legal claim** on the asset. This claim must be enforceable in a court of law. Without a legal wrapper, a token is just a database entry.

Three legal models:

1. **Direct ownership:** Token = legal title (Swiss Registerwertrechte). The token *is* the security.
2. **Indirect claim:** Token = share in a Special Purpose Vehicle (SPV) that owns the asset. Common for real estate.
3. **Contractual right:** Token = promise from issuer. Weakest protection; depends on issuer solvency.

The Critical Question

If the issuer goes bankrupt, does the token holder have a claim on the underlying asset — or just an unsecured claim against the issuer?

Swiss DLT Act: Direct ownership (model 1) — strongest protection

Most US tokens: SPV structure (model 2) — depends on SPV setup

Many DeFi tokens: Contractual only (model 3) — buyer beware

SPV = Special Purpose Vehicle — a separate legal entity created solely to hold the asset. It shields token holders from the issuer's other liabilities.

Layer 2: Custody Models

Self-Custody

Investor holds
private keys directly

Pro: No counterparty risk

Con: Key loss = total loss
Lost keys are irrecoverable

Qualified Custodian

Bank or licensed firm
holds keys on behalf

Pro: Insured, regulated

Con: Reintroduces the
intermediary you removed

Hybrid (MPC)

Multi-Party Computation:
2-of-3 key shards
(investor, custodian, backup)

Pro: No single point of failure

Con: Complex, newer technology

Trend: Institutional adoption favors qualified custodians (BNY Mellon, State Street) or hybrid MPC solutions (Fireblocks, Copper). Pure self-custody remains niche for regulated assets.

Custody is the boring but critical layer. 20% of all Bitcoin is estimated to be permanently lost due to key mismanagement (Chainalysis 2023). Institutional tokenization cannot afford that failure rate.

Layer 3: Issuance Platforms

Platform	Headquarters	Blockchain(s)	Notable Clients	Focus
Securitize	USA	Ethereum, Avalanche	BlackRock, Hamilton Lane	Funds, PE
Tokeny	Luxembourg	Ethereum, Polygon	EIB, Euroclear	EU bonds
Sygnum	Switzerland	Ethereum, Stellar	Swiss banks	Multi-asset
Fireblocks	USA/Israel	70+ chains	BNY Mellon, ANZ	Custody + issuance
Backed	Switzerland	Ethereum, Polygon	Retail, DeFi	Tokenized ETFs
Polymesh	Global	Polymesh (native)	Broadridge	Identity-native

Key insight: No single platform dominates. The market is fragmented by geography, asset class, and regulatory regime. Interoperability between platforms remains an unsolved challenge.

Issuance is the most crowded layer of the stack — dozens of platforms compete, but network effects have not yet produced a winner. Sources: company websites, press releases 2024.

Layers 4–5: Trading and Settlement

Layer 4: Trading **On-chain orderbooks:**

- Limit and market orders executed by smart contracts
- Example: Serum (Solana), dYdX

Off-chain matching, on-chain settlement:

- Traditional matching engine, blockchain for finality
- Example: SDX, Archax, ADDX

Challenge: Liquidity is thin. A tokenized bond with 3 daily trades has worse price discovery than a traditional exchange.

Layer 5: Settlement **Atomic DvP (Delivery versus Payment):**

- Token and payment transfer simultaneously
- Neither party bears counterparty risk
- Executed in a single blockchain transaction

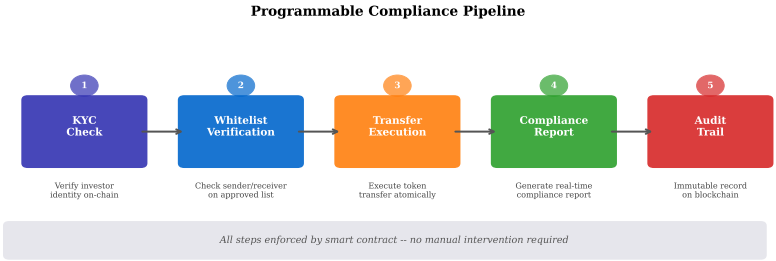
Payment leg options:

- Stablecoin (USDC, USDT)
- Tokenized bank deposit (JPM Coin)
- Wholesale CBDC (Project Helvetia)

Cross-chain: Assets on Ethereum, payment on Stellar? Bridges introduce risk.

DvP = Delivery versus Payment — the principle that securities and cash exchange simultaneously. Atomic DvP on blockchain eliminates settlement risk entirely.

Programmable Compliance



What you see: How compliance rules are embedded into token transfer logic — a transfer request triggers automated checks: (1) Is the sender KYC-verified? (2) Is the receiver in a permitted jurisdiction? (3) Does the transfer exceed holding limits? (4) Is the lock-up period complete? Only if all checks pass does the transfer execute. **Key pattern:** Compliance becomes continuous and automatic, not periodic and manual. **Takeaway:** ERC-1400 tokens enforce regulation at the protocol level — a US-sanctioned entity cannot receive tokens even if they have the wallet address.

KYC = Know Your Customer. AML = Anti-Money Laundering. Programmable compliance shifts enforcement from "audit after the fact" to "prevent before the fact."

Traditional vs Tokenized Markets: Side by Side

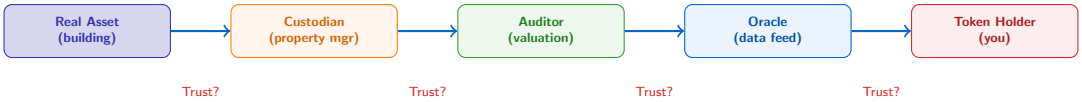
Dimension	Traditional	Tokenized
Settlement speed	T+1 to T+2	T+0 (seconds)
Trading hours	Exchange hours only	24
Minimum investment	$1,000 – $250,000	As low as $1 – $50
Compliance	Manual, periodic audit	Automated, continuous
Intermediaries	Broker, custodian, CSD, CCP	Smart contract, optional custodian
Geographic access	Jurisdiction-limited	Global (with compliance)

Key insight: Tokenized markets are not "better" on every dimension. They trade settlement speed and access for mature liquidity, legal certainty, and institutional trust built over decades.

CSD = Central Securities Depository. CCP = Central Counterparty. Both are intermediaries that tokenized markets aim to replace or absorb.

The Oracle Problem

"How does the blockchain know the building still exists?"



Blockchains guarantee **on-chain** data integrity. But tokenized real-world assets depend on **off-chain** facts: Does the building exist? Is it insured? Is it occupied? Each link in the chain above is a trust point — and none of them are on the blockchain.

Key insight: Tokenization does not eliminate trust — it moves trust from "do I trust my broker?" to "do I trust the oracle and custodian?"

The oracle problem is fundamental: blockchains are deterministic and self-contained, but real-world assets are messy, physical, and subject to change without notice.

The Legal Enforcement Gap

Scenario 1: The Disputed Property

You own 50 tokens representing 5% of an apartment building in Berlin. The property manager stops paying rent to token holders. What do you do?

- Which court has jurisdiction? (Germany? Your country?)
- What legal standing does a token holder have?
- Can 50 token holders coordinate a lawsuit?
- Is the smart contract or the SPV agreement the binding document?

Scenario 2: The Fork

The blockchain hosting your tokenized bond undergoes a hard fork (the network splits into two incompatible versions). You now have bonds on *both* chains. Which one is the "real" bond?

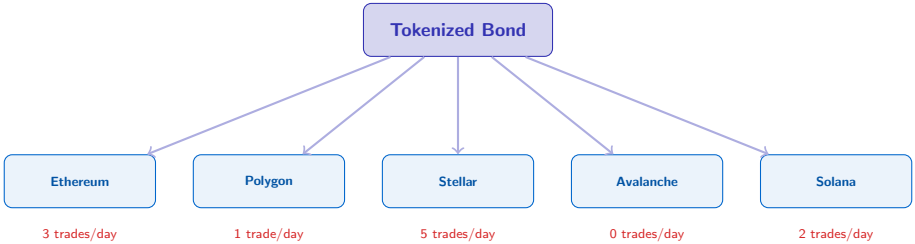
- The smart contract exists on both chains
- The issuer recognizes only one chain
- Courts in different jurisdictions may disagree
- No legal precedent exists (yet)

Key insight: Code is law — until it reaches a courtroom. The legal system and the blockchain system must agree, and right now, the interface between them is fragile.

These are not hypothetical scenarios. The Ethereum/Ethereum Classic fork (2016) raised exactly this question. For tokenized securities, the stakes are much higher.

Liquidity Fragmentation

Problem: A tokenized bond listed on 5 different blockchains = 5 separate, thin order books.

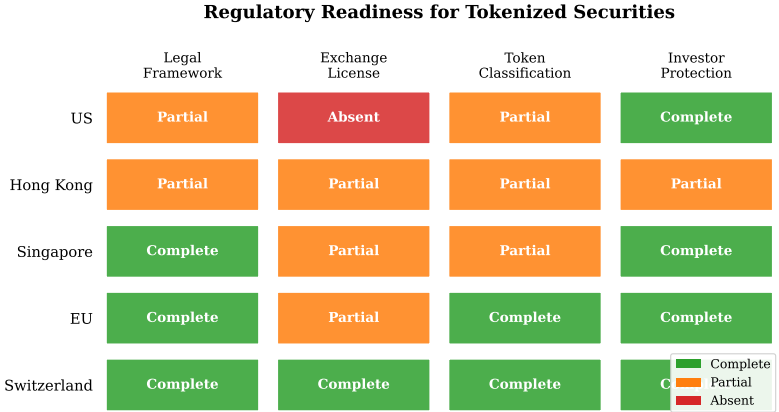


Total: 11 trades/day spread across 5 venues
Traditional exchange: 11 trades in one order book = better price discovery

Key insight: Tokenization *enables* 24/7 trading, but it does not *guarantee* liquidity. Without concentrated order flow, tokenized markets may offer worse execution than traditional ones.

Cross-chain bridges could aggregate liquidity, but they introduce smart-contract risk. Bridge hacks have caused $2.5B+ in losses since 2021 (Chainalysis 2024).

The Regulatory Patchwork

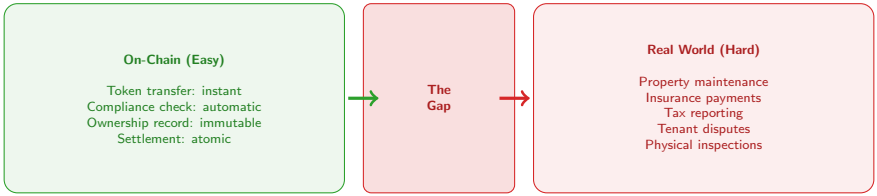


Assessment as of 2025 | Based on enacted legislation and active regulatory programs

What you see: A comparison of regulatory approaches to tokenized securities across jurisdictions — Switzerland (DLT Act: comprehensive, principle-based, technology-neutral), EU (DLT Pilot Regime: sandbox approach, limited scope, temporary), US (fragmented: SEC vs. CFTC jurisdiction unclear, enforcement-driven regulation), Singapore (MAS framework: progressive sandbox, Project Guardian), Hong Kong (dual licensing: SFC for securities, HKMA for banking). **Key pattern:** Jurisdictions that provide legal clarity (Switzerland, Singapore) attract more tokenization activity. **Takeaway:** Regulatory uncertainty is the single biggest barrier to tokenization adoption — larger than any technical challenge.

SEC — Securities and Exchange Commission, CFTC — Commodity Futures Trading Commission, SFC — Securities and Futures Commission (Hong Kong)

The “Last Mile” Problem



Key insight: Tokenization solves the *transfer* problem brilliantly. But real-world assets require *management* — and management cannot be put on a blockchain. Someone must fix the roof, file the taxes, and evict non-paying tenants. That “someone” is an intermediary.

The last mile problem: on-chain operations are trustless and instant, but off-chain obligations remain slow, trust-dependent, and jurisdiction-specific.

What Tokenization Does NOT Solve

Tokenization is infrastructure, not alchemy. It cannot:

1. **Make bad assets good.** A tokenized junk bond is still a junk bond. Fractional ownership of a worthless property creates 10,000 worthless tokens.
2. **Create liquidity from nothing.** If nobody wants to buy a tokenized asset, 24/7 trading hours do not help. Liquidity requires demand, not technology.
3. **Replace legal systems.** Smart contracts execute code, not law. A court order can override any on-chain transaction.
4. **Eliminate all intermediaries.** Custodians, auditors, property managers, and oracles remain necessary for real-world assets.
5. **Guarantee returns.** "Tokenized real estate yielding 12%" carries the same risk as "real estate yielding 12%" — the blockchain adds transparency, not safety.

Key insight: Garbage in, garbage out. Tokenization improves the *plumbing*, not the *product*.

Healthy skepticism: if a tokenized investment sounds too good to be true, the problem is the investment, not the tokenization. Due diligence applies equally to digital and traditional assets.

Key Takeaways

1. **Tokenization is not digitization.** It creates programmable, tradeable ownership claims on a blockchain — fundamentally different from putting a PDF on a server.
2. **The institutional wave is real.** BlackRock, JPMorgan, Franklin Templeton, and SIX have deployed live products, not just pilots. Over $10B in RWA is already on-chain.
3. **Regulation is the enabler, not the barrier.** The Swiss DLT Act and Singapore's MAS framework show that clear regulation accelerates adoption. Jurisdictions without clarity fall behind.
4. **The infrastructure stack has five layers.** Legal wrapper, custody, issuance, trading, settlement. Each layer must work for tokenized markets to function.
5. **Tokenization improves plumbing, not products.** Bad assets do not become good when tokenized. The oracle problem, legal enforcement gaps, and liquidity fragmentation remain real risks.

Five takeaways, one per section: definition, institutional adoption, regulation, infrastructure, and risks.

The $16 Trillion Question

World Economic Forum projection:

$16 trillion

in tokenized assets by 2030

Arguments for:

- BlackRock, Fidelity, and Goldman Sachs are investing
- Regulatory frameworks are maturing globally
- Institutional demand for 24/7 settlement is growing
- Technology is no longer the bottleneck

Arguments against:

- Current RWA on-chain: ~$10B ($16T = 1,600x growth in 4 years)
- Legal frameworks are still fragmented
- Liquidity has not materialized at scale
- WEF projections have been wrong before

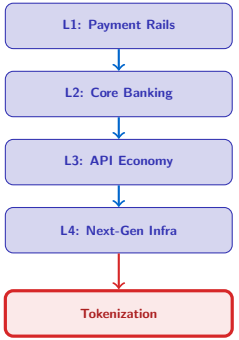
Source: World Economic Forum, "Digital Assets, Distributed Ledger Technology and the Future of Capital Markets," 2021. Updated estimates from Boston Consulting Group (2023) suggest $16T by 2030.

Whether the number is $16T or $4T, the direction is clear: tokenized assets will grow by orders of magnitude. The question is pace, not direction.

Bridge: What This Means for Infrastructure

Tokenization demands new infrastructure:

- **Payment rails (M6 L1):** Must support atomic DvP with stablecoins or CBDC — traditional SWIFT cannot settle tokenized trades
- **Core banking (M6 L2):** Must integrate digital asset custody alongside traditional accounts
- **API economy (M6 L3):** Issuance platforms, oracles, and compliance engines must interoperate via standardized APIs
- **Next-gen infrastructure (M6 L4):** Cloud-native, blockchain-compatible, real-time — the backbone for tokenized markets



Key insight: Tokenization is not a standalone technology — it is the *application layer* that sits on top of modernized financial infrastructure.

This lecture connects back to Module 6's core lessons: without modern payment rails, core banking, APIs, and cloud infrastructure, tokenized markets cannot function at scale.

Further Reading

1. **Swiss DLT Act** — Federal Council Dispatch on DLT (2020). Full text of the legal framework that created Registerwertrechte.
   https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-77252.html

2. **BIS Tokenisation Paper** — "The future monetary system: tokenisation is key" (BIS Annual Economic Report, 2023). Central bankers' vision for tokenized finance.
   https://www.bis.org/publ/arpdf/ar2023e3.htm

3. **BlackRock BUIDL** — Fund documentation and Securitize partnership details.
   https://securitize.io/learn/press/blackrock-launches-first-tokenized-fund-buidl

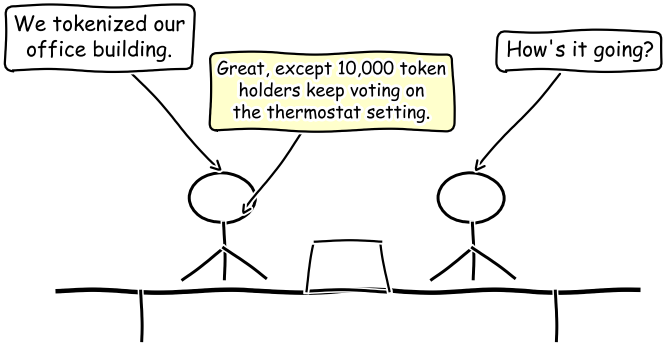
4. **SDX Documentation** — SIX Digital Exchange: technology, regulation, and live products.
   https://www.sdx.com

5. **MAS Project Guardian** — Singapore's multi-asset tokenization pilot with 15+ industry partners.
   https://www.mas.gov.sg/schemes-and-initiatives/project-guardian

6. **RWA.xyz** — Real-time dashboard tracking tokenized RWA on-chain.
   https://www.rwa.xyz

Start with the BIS paper for the macro view, then the Swiss DLT Act for the legal model, then BUIDL and SDX for institutional implementation.

The Tokenized Future



TOKEN ALL THE THINGS

Governance: the part nobody warned you about.

"In 2035, your grandchildren will ask why anyone ever needed a broker to buy a building." — The tokenization revolution is infrastructure, not hype. Build accordingly.

Appendix A: The 2017–2019 STO Promise vs. What Happened

The "Security Token Offering" wave of 2017–2019 made the same pitch as today's RWA wave. The outcomes have been sobering. Any honest tokenization curriculum must include the graveyard.

What was promised (2017–2019)

- **24/7 global markets** for private equity, real estate, fine art
- **Instant liquidity** for historically illiquid assets
- **Fractional ownership** democratising access ($100 into Manhattan real estate)
- **Automated compliance** via token-embedded transfer restrictions (ERC-1400, ERC-1404)
- Projected $24T market by 2027 (*World Economic Forum, "Realizing the Potential of Blockchain" 2018*, 2018) (common consultancy projection)

What actually happened

- **Polymath (POLY token):** down >95% from ATH (*CoinMarketCap Polymath history 2018–2024*, 2024); platform pivoted to Polymesh (its own chain) with modest adoption
- **Harbor:** acquired by BitGo 2020 and wound down as a standalone STO platform
- **tZERO (Overstock spinoff):** ATS volumes declined; valuation markdown; pivot to services
- **Securitize:** pivoted from retail STOs to institutional fund tokenization (BlackRock BUIDL) — a sensible pivot, but the original STO thesis did not succeed
- **SEC enforcement wave:** Kik $5M settlement (*SEC v. Kik Interactive, Sep 2020*, 2020), Telegram TON $1.2B returned + $18.5M fine (*SEC v. Telegram Group, Jun 2020*, 2020), Block.one EOS $24M fine (*SEC v. Block.one, Sep 2019*, 2019)

The structural lesson: "security token" is a legal classification, not a liquidity guarantee. Secondary-market liquidity requires **buyers on the other side of every trade**, which in turn requires broker-dealer infrastructure, market-maker economics, and regulated venues — all of which already exist for equities. Tokenisation does not create liquidity; it reorganises the rails on which liquidity trades.

The current (2024–26) RWA / institutional-tokenisation wave differs from STOs in three ways: regulated-fund-first (BUIDL, Franklin OnChain),

Appendix B: Illiquidity Has Uses — Not Every Asset Should Be Liquid

The tokenisation pitch assumes liquidity is strictly better than illiquidity. Academic finance has taught the opposite for 40 years. A complete curriculum must cover both sides.

What illiquidity actually does

- **Price discovery via discounts:** illiquid assets (private equity, venture) trade at 20–40% illiquidity discounts (*Preqin / Cambridge Associates PE benchmarks 2022*, 2022) vs. public comparables — that discount is a feature, not a bug. It compensates long-horizon capital for bearing lock-up risk.
- **Forced patience / behavioural discipline:** Odean (1999) + many replications show retail investors who can trade frequently *underperform* buy-and-hold by ∼6.5% annually (*Odean, "Do Investors Trade Too Much?" AER 1999*, 1999) from overtrading. Illiquidity is exactly the commitment device that fixes this.
- **Long-term governance alignment:** lock-up periods in VC, private credit, and co-investment structures match investors' horizons to management's

What "tokenise everything" breaks

- Retail access to 24/7 secondary markets in private-equity tokens creates a **retail-panic risk** for assets that should never trade faster than the underlying cash flows
- The illiquidity premium is compensation the investor *earns* — tokenise into liquid markets, the premium compresses, and the product becomes worse, not better, for patient capital
- **Fire-sale dynamics:** 2008 auction-rate-securities market froze overnight once participants realised "liquid" status was a convention, not a property. Tokenised real estate could do the same in a cycle downturn.
- Regulatory / suitability case: should retail be able to exit private equity at 3am Sunday? Is that a feature?

The honest claim: tokenisation is a strong fit where existing liquidity is already organized but infrastructure is costly (money-market funds → BUIDL, T-bills → BENJI). It is a weak fit where illiquidity is an *intentional design feature* of the product (most PE, VC, infrastructure funds). The excitement pattern of 2017 STOs — "make illiquid things liquid" — misread what illiquidity was doing.

Foundational reading: Amihud & Mendelson (1986) on the illiquidity premium; Pastor & Stambaugh (2003) on liquidity risk pricing; Koijen & Yogo (2019) on demand-system asset pricing. Tokenise only where the liquidity premium can be captured without destroying the illiquidity premium — not a trivial design question.