Table of Contents

Crypto-assets: the apparatus and its distribution

Umbrella research volume of the cluster KRYPTOWERTE-VOLLWERK — state of research 2024–2026 across nine axes

Thomas Schüller · Syntagma Forschung · Vienna · ORCID 0009-0003-9799-6747 As of: 20 October 2026 · Threshold B · CC BY 4.0

Summary

The field of crypto-assets can be worked up completely along nine disciplinary axes, and each one shows the same pattern: the power of disposition sits with a few, while the costs and risks are borne by many. Decentralisation is real at the protocol level but heavily concentrated at every deeper layer. This umbrella volume consolidates the 2024–2026 state of research as a foundation for the cluster's individual volumes and makes the risk–disposition asymmetry (rho/delta) the guiding instrument of the analysis.

Three figures frame the situation: three mining pools suffice for 51 percent of Bitcoin's hashrate. Three manufacturers supply over 99 percent of mining hardware (Bitmain ~82 %, MicroBT ~15 %, Canaan ~2 %). And according to the Bank for International Settlements, 73 to 81 percent of retail investors lost money on their first Bitcoin investments, while large holders sold during the downturns.

---

1. The guiding matrix: disposition versus risk

The cluster's distinctive contribution is not retelling the technology but reading it along a single question: who disposes, and who bears? The matrix below sorts each stakeholder by power of disposition (delta) and risk borne (rho).

Stakeholder	Power of disposition (delta)	Risk / cost borne (rho)	Evidence
Retail investors	low (price-takers, custody mostly at exchange)	price losses, exchange failures, fraud, hacks	BIS 2023; FTX 2022
Whales / early holders	high (market power, timing)	low — sell first in shocks	BIS Bulletin 69; Makarov/Schoar 2021

Stakeholder	Power of disposition (delta)	Risk / cost borne (rho)	Evidence
Miners / pool operators	high (transaction selection)	capital/hardware risk, halving shocks	b10c 2025
ASIC makers / foundries	very high (supply bottleneck, firmware)	geopolitics (Taiwan, tariffs)	Cambridge 2025
Validators / liquid staking	high (consensus weight under PoS)	slashing, regulation	Lido 2025/26
Centralised exchanges (CEX)	very high (custody, listing)	hack/insolvency mostly hits customers	FTX 2022; Bybit 2025
Developers / foundations	high (code, upgrades, governance)	criminal liability (Storm case)	SDNY 2025
Stablecoin issuers	very high (seigniorage, freeze function)	run risk shifted onto holders	BIS 2025/26; GENIUS Act
State / central bank	regulation, sanctions, taxation	loss of monetary sovereignty	IMF/El Salvador
Grid neighbours	negligible	electricity prices, noise, water	de Vries 2023; Cambridge 2025
Future generations	none	CO_2, e-waste, quantum legacy	de Vries/Stoll 2021
Global South	low	crypto-dollarisation, shock losses	BIS 2023

The asymmetry is not accidental; it follows from the architecture: economies of scale in hashrate, stake and liquidity, and network effects at exchanges and stablecoins, all push toward concentration, while external costs (emissions, grid load, e-waste) are not reflected in the price.

---

2. The nine axes at a glance

2.1 Technology and protocols

Proof of Work (Bitcoin, SHA-256d, the April 2024 halving to 3.125 BTC, hashrate ~850–1,000 EH/s) stands against Proof of Stake (Ethereum since the 2022 Merge, 32 ETH per validator, slashing), alongside DPoS, Proof of Authority, Solana's Proof of History and the BFT family (PBFT, Tendermint). Nakamoto consensus gives probabilistic finality via the longest chain; classical BFT gives instant finality with a known validator set. 51-percent attacks are real (Bitcoin Gold 2018/2020, Ethereum Classic four times in 2019/2020), mostly with rented hashrate. Scaling runs through Layer 2 (optimistic vs. ZK rollups), Lightning and sharding; the most vulnerable point is bridges (Ronin ~$625m, Wormhole ~$320m).

2.2 Cryptography

Signatures via ECDSA/secp256k1, and Schnorr since Taproot; hash functions SHA-256 and Keccak; zero-knowledge schemes (zk-SNARKs with trusted setup, transparent zk-STARKs, Bulletproofs). Privacy primitives: Monero (ring signatures, RingCT, stealth addresses), Zcash (zk-SNARKs, shielded/transparent). The post-quantum threat is concrete: Shor's algorithm breaks the elliptic curve once a public key is exposed — one estimate puts ~6.7m BTC at exposure. Bitcoin's migration path (BIP-360) has been in progress since September 2024; the first plausible window for relevant quantum computers is given as 2027–2033 (with wide error bars, to be labelled as a forecast).

2.3 Hardware

Mining hardware evolved from CPU through GPU and FPGA to ASIC. The market is oligopolistic: over 99 percent from three makers, all fabless (production at TSMC and Samsung). Bitcoin's security therefore hangs geopolitically on Taiwan and competes with AI chips for fab capacity. Hardware wallets (Ledger, Trezor) use secure elements; the 2025 Bybit hack showed the weak point was the signing orchestration, not the cryptography.

2.4 Electricity, energy, resources, environment

The Cambridge index estimates Bitcoin's electricity use at ~138 TWh/year (~0.5 % of world electricity), with a methodological range of 74 to 242 TWh; Digiconomist gives ~204 TWh. Emissions are ~39.8 Mt CO_2e. The power mix is ~52 % "sustainable" (renewables plus nuclear), ~38 % natural gas. Add water use (~2,237 GL in 2023 per de Vries) and e-waste (~30.7 kt/year). Ethereum's Merge cut consumption by ~99.99 percent — the consensus choice is also an environmental decision. Ecologically, PoW is a commons and externality problem: consumption is coupled to price, and the costs fall on the atmosphere and water resources.

2.5 Economics, macro and micro

In monetary theory Bitcoin is a digital metallism (fixed supply, no lender of last resort), close to Hayek's denationalisation of money; chartalism and MMT instead locate money's value in the tax obligation. Fiat versus crypto differs on every dimension (unit of account, elasticity, deposit insurance, seigniorage). Macro: crypto-dollarisation looms (~99.5 % of stablecoins are USD-denominated) along with loss of sovereignty; the BIS in 2026 finds stablecoins weak on "singleness, elasticity, integrity." El Salvador reversed its Bitcoin law on 29 January 2025 under IMF pressure. Micro: 73–81 percent retail losses (BIS), over 70 percent wash trading on unregulated exchanges (Cong et al. 2023), Tether-driven price support in 2017 (Griffin/Shams 2020), extreme holding concentration (top 0.1 % of miners ~50 % of capacity).

2.6 Coins and systems

Bitcoin as store of value, Ethereum as smart-contract base, plus Layer-1 competitors (Solana, Cardano, Avalanche, Polkadot, BNB), stablecoins (market ~$308–322bn, USDT ~59 %, USDC ~23 %), privacy coins, memecoins, utility/security/governance tokens. DeFi (Uniswap, Aave, Lido) moves financial functions into smart contracts; NFTs boomed and busted in 2021/22; DAOs are formally member rule, in fact token plutocracy. The 2017/18 ICO wave (~$12bn) was

~78–81 percent fraud by project count per Satis; only 44.2 percent of startups still existed 120 days after their ICO.

2.7 Anonymity versus transparency

Bitcoin and Ethereum are pseudonymous, not anonymous; clustering heuristics and KYC points enable de-anonymisation. Blockchain forensics (Chainalysis, TRM) attributes illicit flows — still under 1 percent of volume, ~84 percent of it in stablecoins. Privacy coins (Monero, Zcash) are under regulatory pressure: the EU AMLR bans anonymity-enhancing coins at service providers from 2027; Binance, Kraken and OKX delisted Monero in 2024. The Tornado Cash case marks the fault line: code itself is not sanctionable (Van Loon v. Treasury, 2024; delisting 2025), but developers face criminal liability (Storm, 2025).

2.8 Centralised versus decentralised

Mining pools are concentrated (Foundry and AntPool together 60–70 %); in Ethereum staking Lido holds ~21–25 percent. Centralised exchanges are the re-erected centre: FTX collapsed in 2022 (Bankman-Fried, 25 years), Bybit suffered the largest crypto theft in history in 2025. “Decentralisation theatre” means admin keys, central sequencers, foundation treasuries and concentrated token governance.

2.9 Law and regulation

MiCA (EU Regulation 2023/1114) has applied in full since 1 July 2026, with no transitional period; complemented by DORA and the Transfer-of-Funds Regulation (travel rule). The US turned in 2025: the GENIUS Act (18 July 2025) legalises stablecoins with 1:1 reserves and holder priority in insolvency; the SEC case against Coinbase was dismissed, Tornado Cash delisted. China has banned mining and trading since September 2021. In Germany, private disposal gains remain tax-free after one year; the DAC8 reporting duty applies from 2026.

---

3. Transdisciplinary cross-links

The convergence of the axes is the real yield. The consensus choice is also an environmental decision (axis 1 ↔ 4). The immutability of smart contracts disables the sanctions power and forces the law onto developer liability and gatekeepers (1 ↔ 9). Bitcoin’s security hangs on TSMC and tariff policy (3 ↔ 5). The BIS data empirically refute the democratisation narrative (5 ↔ 8). The quantum migration is an intergenerational distribution problem (2 ↔ ethics). And both the GENIUS Act and MiCA regulate issuers in the North, while the Global South bears the dollarisation consequences (9 ↔ stakeholders).

---

4. Research gaps for the individual volumes

Five gaps the cluster should fill, marked open after literature scouting:

- **O-1 — Neutral life-cycle assessment.** A methodologically clean comparison of PoW with gold and the banking system over a shared functional unit is missing; existing comparisons come from interest groups. [open → Resources/Ecology volume]
- **O-2 — Retail losses in the EU after MiCA.** Micro-data on the loss distribution under the new framework are missing. [open → Financial economics volume]
- **O-3 — Stablecoins and monetary sovereignty.** The effect on bank deposits and capital controls in emerging markets is not conclusively studied. [open → Financial economics/Law volume]
- **O-4 — Governance concentration.** Concentration measures for DAOs and Layer 2 are systematically missing. [open → Centralised/Decentralised volume]
- **O-5 — Distributional consequences of quantum migration.** Who bears the risk of unmigrated keys, who gains from early quantum hardware? [open → Cryptography/Ethics volume]

---

5. Methodological caveats

The state of research must be carried as ranges, not point values: electricity 138 TWh (range 74–242) versus Digiconomist ~204 TWh; illicit volume Chainalysis $154bn versus TRM $158bn. Interest-bound sources (Chainalysis, TRM, Lido self-reporting, CCRI commissioned by ConsenSys, the Cambridge survey with 48 % coverage and a US skew) are to be labelled as such. Makarov/Schoar is a non-peer-reviewed working paper; the figure for quantum-exposed BTC comes from a quantum-security vendor. Forecasts (the 2027–2033 quantum window, stablecoin projections to 2030, the effect of the not-yet-fully-in-force GENIUS Act) are to be marked explicitly as forecasts. Data as of October 2026; the market and US regulation change fast. Before publication, pool shares, stablecoin market data, the number of authorised CASPs and the bridge-hack totals must be verified at the primary source.

---

6. Cluster structure (slug-led)

Anchor works already produced: `anleitung-und-risiko` (Hosp critique, period document), `vertrauen-ohne-mitte` (full treatise), `geld-die-erste-mitte` (A01 monetary theory), `die-abgeschaffte-mitte` (A02 cryptographic prehistory). Planned individual volumes: consensus/protocol informatics, financial economics/market, law/regulation, resources/ecology, centralised/decentralised, anonymity/transparency, ethics/rho-delta formalisation, outlook/governance. All numbers provisional; to be fixed against `forsch-reg` (frontier as of 2026-10-20 at PROV ~0470).

Sources

Primary: EUR-Lex (Reg. 2023/1114 MiCA; Reg. 2022/2554 DORA; Reg. 2023/1113 Transfer-of-Funds); ESMA statements 2026; GENIUS Act (Public Law 119-27, 18 July 2025); IMF Country Reports El Salvador 25/58 and 25/68; BIS Bulletin 69 (Cornelli et al. 2023) and BIS Annual Report 2025/2026; FATF Targeted Update 2026; Nakamoto 2008; Haber/Stornetta 1991; BIP-

360. Studies: Cong/Li/Tang/Yang, *Crypto Wash Trading*, Management Science 69(11) 2023; Griffin/Shams, *Is Bitcoin Really Untethered?*, Journal of Finance 75(4) 2020; Makarov/Schoar, NBER WP 29396 (2021); de Vries, *Bitcoin's growing water footprint*, Cell Reports Sustainability 1(1) 2023; de Vries/Stoll 2021; Benedetti/Kostovetsky, *Digital Tulips?*, Journal of Corporate Finance 66 (2021). Industry/measurement sources (interest-bound, flagged): Cambridge CBECI and Digital Mining Industry Report 2025; Digiconomist; Chainalysis/TRM crime reports 2026; Lido reports; CCRI 2022.

All research: Thomas Schüller · Syntagma Forschung · Vienna · ORCID 0009-0003-9799-6747 · *CC BY 4.0. Derived from a structured extended-research analysis (state 2024–2026); interest-bound sources flagged, forecasts marked as such.*