

Bitcoin-Seconds (BXS): Measuring Durable Accumulation of Time-Shifted Energy Claims

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Abstract

Bitcoin converts present energy expenditure into cryptographically proven, transferable claims on future energy and work. We propose a Bitcoin-native temporal calculus that measures the *durability* of those claims through time. The framework forms a three-level ladder: (i) an instantaneous flow $f(t)$ in satss^{-1} capturing the rate of accumulating *durable* energy claims, (ii) its cumulative integral $S(T)$ in sats, and (iii) the time-weighted integral $\text{BXS}(T)$ in $\text{sats}\cdot\text{s}$ (Bitcoin-Seconds). Each driver of durability is observable: income velocity, revealed HODLing strength (coin age), protocol dilution (mechanical inflation), and financial runway. We state falsifiable hypotheses, a node-local implementation, and a backtest recipe to validate that durability-aware measures add information beyond balance, coin age, and ROI.

1 Foundation: Bitcoin as Time-Shifted Energy Claims

Proof-of-Work turns present energy expenditure into a cryptographic record that persists and becomes a transferable claim on future energy and work. When Satoshi mined 50 BTC per block in 2009–2010, the marginal dollar cost of electricity was tiny; today that same 50 BTC can command millions of dollars in labor and energy. Thus, energy expended in 2009 was preserved as a transferable claim across sixteen years of halvings, market cycles, and protocol upgrades. *This temporal persistence of energy claims is what Bitcoin-Seconds aims to measure.* We seek to quantify not only *how much* Bitcoin is held or earned, but *how durably* those claims persist through time and conditions.

2 Measurement Problem: Durable vs. Transient Accumulation

Not all Bitcoin accumulation is equal. Some flows are quickly liquidated (transient), others are held and financially sustainable (durable). We ask: *What is the rate at which an entity accumulates durable energy claims, and how does that durability persist through time?*

3 Drivers and Notation

Let $t \in [0, T]$ be time in seconds. All series are assumed piecewise continuous and integrable on $[0, T]$.

- $i(t)$: income inflow [sats s^{-1}].
- $\mu(t)$: spending outflow [sats s^{-1}].
- $A(t)$: value-weighted coin age (revealed HODLing strength) [s].
- $I(t)$: protocol monetary expansion rate [s^{-1}], defined mechanically as

$$I(t) = \frac{\sigma(h(t))}{S(t)} \lambda(t),$$

where subsidy σ is in BTC per block, circulating supply S in BTC, and λ is blocks per second.

- $s(t)$: current holdings [sats].
- r : retirement (forward) horizon [s].
- $CP(t)$: cumulative inflation-adjusted cost (optional) [sats].

Baselines. Choose positive baselines $A_0 > 0$ and $I_0 > 0$ for normalization. Unless stated otherwise: A_0 is a rolling 180-day median of $A(t)$ per entity; I_0 is a per-epoch rolling median of $I(t)$. We will evaluate robustness to baseline windows in sensitivity checks.

Surplus-to-Spending Ratio (SSR). *Intuition:* SSR measures *financial runway*: how long can holdings sustain current spending, adjusted for future income?

$$\text{SSR}(t) = \frac{s(t) + r i(t) - CP(t)}{\max\{t, t_{\min}\} \max\{\mu(t), \mu_{\min}\}} \quad (\text{dimensionless}).$$

Numerator: current savings plus forward income capacity minus past costs. Denominator: elapsed time multiplied by present spending rate. Floors $t_{\min} > 0$, $\mu_{\min} > 0$ avoid division by zero at startup or near-zero spending. Negative $\text{SSR}(t)$ indicates drawdown pressure; we do not clip negatives.

4 Instantaneous Flow of Durable Claims

$$f(t) = i(t) \cdot \frac{A(t)}{A_0} \cdot \frac{I(t)}{I_0} \cdot \text{SSR}(t)$$

(1)

Units and meaning. $f(t)$ is in sats s^{-1} (BTC/s or sats/s). It is the *rate of accumulating durable energy claims*, i.e., income weighted by:

1. $A(t)/A_0$: revealed HODLing strength (demonstrated time preference),
2. $I(t)/I_0$: protocol-era context (dilution/halving environment),
3. $\text{SSR}(t)$: financial runway to maintain claims (ability vs. intent).

At-a-glance recap.

$$\text{SSR}(t) = \frac{s(t) + r i(t) - CP(t)}{\max\{t, t_{\min}\} \max\{\mu(t), \mu_{\min}\}}, \quad S(T) = \int_0^T f(t) dt, \quad \text{BXS}(T) = \int_0^T S(t) dt.$$

Why multiplicative? Durable accumulation requires all dimensions to align; failure in any one dimension (e.g., no runway, low age, high dilution) lowers effective durable flow. Multiplication captures these interaction effects parsimoniously.

Ladder Schema (informational)

Level 1 (Flow): $f(t)$ in sats s^{-1} \rightarrow rate of accumulating *durable* energy claims.

Level 2 (Stock): $S(T) = \int_0^T f(t) dt$ in sats \rightarrow total durable claims accumulated.

Level 3 (Time-Weighted): $\text{BXS}(T) = \int_0^T S(t) dt$ in $\text{sats}\cdot\text{s}$ \rightarrow persistence of claims (amount and duration).

Baseline comparator (size-only): $\text{BXS}_{\text{core}}(T) = \int_0^T W(t) dt$.

Figure 1: $\text{BTC/s} \rightarrow \text{BTC} \rightarrow \text{BTC}\cdot\text{s}$ ladder and interpretation.

5 Integration Ladder: $\text{BTC/s} \rightarrow \text{BTC} \rightarrow \text{BTC}\cdot\text{s}$

5.1 Level 1: Flow

$f(t)$ in sats s^{-1} : rate of accumulating durable energy claims.

5.2 Level 2: Stock

$$S(T) = \int_0^T f(t) dt \quad [\text{sats}] \quad (2)$$

5.3 Level 3: Time-Weighted Stock (Bitcoin-Seconds)

$$\text{BXS}(T) = \int_0^T S(t) dt = \int_0^T \int_0^t f(\tau) d\tau dt \quad [\text{sats}\cdot\text{s}] \quad (3)$$

Baseline persistence. For benchmarking, define the size-only persistence

$$\text{BXS}_{\text{core}}(T) = \int_0^T W(t) dt \quad [\text{sats}\cdot\text{s}] \quad (4)$$

with $W(t)$ the balance in sats . This omits durability adjustments. Optionally, discount by $e^{-\rho t}$ for time preference.

Units callout. $f(t)$: BTC/s (sats/s). $S(T)$: BTC (sats). $\text{BXS}(T)$: $\text{BTC}\cdot\text{s}$ ($\text{sats}\cdot\text{s}$).

Scaling for readability. Report BXs also in $\text{BTC}\cdot\text{years}$ by dividing by 31,536,000, i.e., $\text{BXS}^{(\text{yr})} = \text{BXS}/(365 \cdot 24 \cdot 3600)$.

6 Mechanical Inflation $I(t)$ and Per-Block Form

We compute $I(t)$ from node-local telemetry:

$$I(t) = \frac{\sigma(h(t))}{S(t)} \lambda(t),$$

which automatically reflects halving epochs and cadence variation. For block-indexed code, a per-block constant form is useful:

$$I_k = \frac{\sigma_k}{S_k} \cdot \frac{1}{\tau_{\text{target}}} \quad \text{with} \quad \tau_{\text{target}} = 600 \text{ s},$$

and an empirical per-second series obtained by smoothing observed inter-block times.

7 Comparative View of Metrics

Table 1: What each metric captures and misses.

Metric	Captures	Misses	Use Case
Balance $W(t)$	Amount held (size)	Duration, behavior, runway, network era	Snapshot wealth
Coin Age $A(t)$	HODLing duration (revealed behavior)	Size, financial capacity, network era	HODL strength
ROI (fiat)	Fiat-relative returns	Bitcoin-native dynamics, durability	Fiat-world performance
BXS_{core}	Size \times Time (persistence)	Durability factors (A/I/SSR)	Neutral persistence
BXS (durability)	Size \times Time \times HODLing \times Network \times Runway	Aims to miss nothing	Durable claim accumulation

8 Illustrative Magnitudes (Orientation Only)

Satoshi-like holder (size-only core)

Let $W \approx 9.68452 \times 10^{13}$ sats and $T \approx 4.0 \times 10^8$ s. Then

$$\text{BXS}_{\text{core}}(T) \approx W T \approx 3.87 \times 10^{22} \text{ sats}\cdot\text{s} (\approx 1.23 \times 10^{15} \text{ sats}\cdot\text{yr}).$$

This anchors the scale of raw persistence without durability adjustments.

Table 2: Three-point illustration (orders of magnitude only). Baselines: $A_0 = 3.0 \times 10^7$ s, $I_0 = 2.6 \times 10^{-10} \text{ s}^{-1}$; floors: $t_{\min} = 10^3$ s, $\mu_{\min} = 10^{-6} \text{ satss}^{-1}$.

Case	W (sats)	A/A_0	I/I_0	SSR	f (sats/s)
Satoshi-like	9.68×10^{13}	13.3	115.4	2.4×10^9	3.7×10^{12}
Modest (~ 1.2 BTC)	1.2×10^8	1.0	1.0	10^2	10^4
Micro (0.001337 BTC)	1.34×10^5	0.07	1.0	10^1	3×10^1

Numbers are illustrative only; calibrated estimates require entity-specific series.

9 Implementation (Node-Local, Sovereign)

All inputs are computed from a Start9-hosted *mempool.space* and wallet logs:

- $I(t)$ from subsidy, supply, and measured cadence.
- $A(t)$, $W(t)$, $i(t)$, $\mu(t)$ from UTXO histories and inflow/outflow rates.
- $CP(t)$ optional; omit for strictly Bitcoin-native analysis.
- Floors t_{\min}, μ_{\min} applied as in the SSR definition.

This ensures privacy, integrity, and reproducibility without third-party APIs.

10 Empirical Design: Durability and Stress Tests

Hypotheses (falsifiable)

- H1 (Durability): Higher $f(t)$ predicts sustained holding in $[t, t + \Delta]$, controlling for $W(t)$ and $A(t)$. Survival analysis is also applicable.
- H2 (Stress): Declines in $f(t)$ precede forced liquidation (large outflows or UTXO consolidation) earlier than balance-only signals. Evaluate with early-warning ROC curves.
- H3 (Component Decomposition): Each durability component adds statistically significant predictive power in nested model tests. Define models:
 - M1: HOLD $\sim W(t)$
 - M2: HOLD $\sim W(t), A(t)$
 - M3: HOLD $\sim W(t), A(t), I(t)$
 - M4: HOLD $\sim W(t), A(t), I(t), \text{SSR}(t)$
 - M5 (full): HOLD $\sim W(t), A(t), I(t), \text{SSR}(t), f(t)$

Compare with likelihood ratio tests and AIC/BIC; report out-of-sample AUC and Brier score deltas.

Concrete backtest recipe

1. **Label outcomes:** For each entity and evaluation date t , mark HOLD=1 if no net outflow beyond $x\%$ over $[t, t + \Delta]$ (e.g., $\Delta = 90$ days, $x = 5\%$), else HOLD=0.
2. **Models:** Baseline logistic: HOLD $\sim W(t), A(t)$. Durability model: HOLD $\sim W(t), A(t), f(t)$ (and optionally lags/EMAs).
3. **Compare:** AUC and Brier score out-of-sample via rolling-origin CV. Report deltas (Durability minus Baseline).

Stress metric (optional). Define $f^-(t) = \min\{f(t), 0\}$. Test whether f^- leads subsequent spending bursts and drawdown events.

Normalized uplift (optional). Define $\hat{f}(t) = f(t)/(i(t) + \epsilon)$ to show durability uplift over bare income.

11 Applications

- **Individuals:** Personal durability dashboard; track $f(t), S(T), \text{BXS}(T)$; alerts when runway weakens.
- **Analytics:** Identify cohorts likely to hold vs. capitulate; map durability across the UTXO set.
- **Forecasting:** Early warning for capitulation events based on $f(t)$ deterioration.
- **Treasury:** Corporate treasuries can monitor durability to guide cash management and issuance.
- **Research:** Compare durability dynamics across miners, exchanges, whales, retail; study post-halving regimes.

12 Conclusion

This paper introduced a durability-aware ladder $f \rightarrow S \rightarrow \text{BXS}$ that measures the rate, size, and temporal persistence of Bitcoin-denominated energy claims. The construction is Bitcoin-native: it begins with an instantaneous flow $f(t)$ in sats/s that weights income by revealed HODLing strength, protocol-era dilution, and financial runway; integrates to a cumulative stock $S(T)$ in sats; and integrates again to a time-weighted store $\text{BXS}(T)$ in sats·s (Bitcoin-Seconds). In doing so, it distinguishes *durable* accumulation from mere balance growth, providing a principled way to quantify how credibly energy claims persist through time.

Substantive contribution. The framework reframes Bitcoin as *time-shifted energy claims* and operationalizes durability via three observable drivers: (i) demonstrated holding behavior (coin-age), (ii) mechanical supply context (protocol expansion), and (iii) financial capacity to maintain claims (surplus-to-spending runway). The multiplicative form captures the fact that failure in any one dimension erodes sustainable accumulation, while the integration ladder yields interpretable levels (flow, stock, time-weighted stock) with clean units.

Practical relevance. For individuals and treasuries, $f(t)$ functions as a real-time *durability signal*: it can complement balance, DCA plans, and risk budgets by indicating whether accumulation is likely to persist under stress. For analysts, $\text{BXS}(T)$ and $\text{BXS}_{\text{core}}(T)$ separate *size-only persistence* from *durability-adjusted persistence*, enabling cohort comparisons (miners, exchanges, whales, retail) and regime studies across halving epochs. For forecasters, declines in $f(t)$ offer a candidate early-warning indicator of capitulation risk that balance- or ROI-based metrics may miss.

Empirical program. We outlined falsifiable tests: (H1) whether higher $f(t)$ predicts sustained holding, (H2) whether deteriorations in $f(t)$ precede forced liquidation, and (H3) whether each component (coin-age, protocol rate, runway) adds incremental predictive power beyond balance and coin-age alone. A node-local implementation (Start9 + mempool.space) supports reproducibility without third-party dependencies, and a rolling-origin backtest with AUC/Brier comparisons and nested model tests (LR, AIC/BIC) provides an auditable validation path.

Limitations and open questions. The SSR term introduces modeling choices (e.g., floors, retirement horizon, treatment of contingent liabilities) that warrant sensitivity analysis. Coin-age can be confounded by UTXO management practices; robust value-weighting and address clustering are needed. Mechanical $I(t)$ is well-defined, but its *economic* weight may vary by cohort and epoch; this suggests exploring time-varying or cohort-specific baselines (A_0, I_0). Lastly, interpretability under extreme conditions (near-zero spending, abrupt income shocks) motivates guardrails and capped variants for production dashboards.

Extensions. Natural next steps include: discounting $\text{BXS}(T)$ by explicit time preference; decomposing $f(t)$ into permanent vs. transitory components via state-space models; cohort-level durability maps on the UTXO set; and policy applications (e.g., corporate treasury stress testing) where durability thresholds trigger risk actions. A standardized BXS reporting schema (with BTC·s and BTC·years views) would aid comparability across entities.

Outlook. If validated, durability-aware flow $f(t)$ and its integrals $S(T)$, $\text{BXS}(T)$ provide a parsimonious, empirically testable lens on Bitcoin’s core phenomenon: the transport of past energy expenditure into durable, future claims. By measuring not only how much is held, but how credibly it will be *held through time*, the Bitcoin-Seconds framework offers actionable guidance for savers, treasuries, and researchers, and a foundation for a broader time-based economics rooted in verifiable on-chain data.

Appendix A: Units and Dimensional Checks

$$[f] = \text{sats s}^{-1}, \quad [S] = \text{sats}, \quad [\text{BXS}] = \text{sats}\cdot\text{s}.$$

Each integration adds one factor of time, ensuring dimensional closure. Reporting BXS in BTC·yr or sats·yr improves readability.

Appendix B: Edge Cases and Well-Posedness

- $t \rightarrow 0$: use $t \leftarrow \max\{t, t_{\min}\}$.
- $\mu(t) \rightarrow 0$: use $\mu(t) \leftarrow \max\{\mu(t), \mu_{\min}\}$. Interpret very small μ as large runway; optionally cap SSR at SSR_{\max} in production dashboards.
- Negative SSR: retain as a signal of drawdown pressure.
- Baselines A_0, I_0 : use rolling medians; sensitivity-test 90/180/360-day windows and per-epoch settings.

Appendix C: Mechanical Form of $I(t)$

$$I(t) = \frac{\sigma(h(t))}{S(t)} \lambda(t), \quad I_k = \frac{\sigma_k}{S_k} \cdot \frac{1}{\tau_{\text{target}}}, \quad \tau_{\text{target}} = 600 \text{ s}.$$

Empirical cadence can deviate from target; smooth inter-block times to estimate a per-second $I(t)$.

Addendum: Glossary, Worked Examples, and How-To

A. Glossary of Symbols (units in brackets)

$i(t)$	income inflow [sats s ⁻¹]
$\mu(t)$	spending outflow [sats s ⁻¹]
$A(t)$	value-weighted coin age (HODLing strength) [s]
A_0	coin-age baseline (e.g., rolling median) [s]
$I(t)$	protocol expansion rate [s ⁻¹]
I_0	expansion-rate baseline [s ⁻¹]
$s(t)$	current holdings [sats]
r	retirement (forward) horizon [s]
$CP(t)$	cumulative CPI-weighted cost (optional) [sats]
$SSR(t)$	surplus-to-spending ratio [1]
$f(t)$	productive flow of durable claims [sats s ⁻¹]
$S(T)$	cumulative durable claims [sats]
$BXS(T)$	Bitcoin-Seconds (time-weighted claims) [satss]
$BXS_{\text{core}}(T)$	baseline time-weighted wealth $\int_0^T W(t) dt$ [satss]
$W(t)$	wealth (balance) [sats]

Definitions.

$$\begin{aligned} SSR(t) &= \frac{s(t) + r i(t) - CP(t)}{\max\{t, t_{\min}\} \max\{\mu(t), \mu_{\min}\}}, \quad I(t) = \frac{\sigma(h(t))}{S(t)} \lambda(t), \\ f(t) &= i(t) \cdot \frac{A(t)}{A_0} \cdot \frac{I(t)}{I_0} \cdot SSR(t), \quad S(T) = \int_0^T f(t) dt, \quad BXS(T) = \int_0^T S(t) dt. \end{aligned}$$

B. Worked Example 1: Satoshi-like Holder (orientation)

Purpose: orders of magnitude; not a calibrated historical series.

- Holdings: $W \approx 9.68452 \times 10^{13}$ sats; horizon $T \approx 4.0 \times 10^8$ s.
- Baselines: $A_0 = 3.0 \times 10^7$ s; $I_0 = 2.6 \times 10^{-10}$ s⁻¹.
- Snapshot drivers (illustrative): $A = 4.0 \times 10^8$ s; $I = 3.0 \times 10^{-8}$ s⁻¹; $i = 1.0$ sats s⁻¹; $\mu = 1.0 \times 10^{-4}$ sats s⁻¹; $r = 2.0 \times 10^9$ s; $CP = 0$.

$$SSR \approx \frac{9.68452 \times 10^{13} + 2.0 \times 10^9}{(4.0 \times 10^8)(1.0 \times 10^{-4})} \approx 2.42 \times 10^9, \quad \frac{A}{A_0} \approx 13.33, \quad \frac{I}{I_0} \approx 115.4,$$

$$f(t) \approx 3.7 \times 10^{12} \text{ sats s}^{-1}, \quad S(T) \approx 1.5 \times 10^{21} \text{ sats}, \quad BXS(T) \approx 3.0 \times 10^{29} \text{ sats s}.$$

Baseline size-only persistence:

$$BXS_{\text{core}}(T) = W T \approx 3.87 \times 10^{22} \text{ sats s} \quad (\approx 1.23 \times 10^{15} \text{ sats yr}).$$

C. Worked Example 2: Regular Stackers (relatable)

Illustration only. Monthly DCA of USD 500 yields an average inflow $i(t)$ (converted to sats/s) while spending $\mu(t)$ remains below $i(t)$. As $W(t)$ grows from 0 to 10^7 sats over 24 months and $A(t)$ rises with consistent HODLing, SSR improves as the stack covers more months of spending. The durability-aware $f(t)$ reflects this uplift, whereas balance alone would miss it.

D. How-To (Start9 + mempool.space)

1. Compute $I(t)$ mechanically: query σ, S, λ from your node; set $I(t) = \sigma/S \cdot \lambda$.
2. Derive wallet series: $W(t), A(t)$ (value-weighted mean age), $i(t), \mu(t); CP(t)$ optional.
3. Choose A_0, I_0 baselines (rolling medians) and floors t_{\min}, μ_{\min} .
4. Evaluate $f(t)$ each block interval; integrate numerically for $S(T)$ and $\text{BXS}(T)$.
5. Report both BXS_{core} (size-only) and durability-aware BXS .