

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

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

where subsidy  $\sigma$  is in BTC per block, circulating supply  $S$  in BTC, and  $\lambda$  is blocks per second.

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

**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

$$f(t) = i(t) \cdot \frac{A(t)}{A_0} \cdot \frac{I(t)}{I_0} \cdot \text{SSR}(t) \quad (1)$$

**Units and meaning.**  $f(t)$  is in  $\text{sats s}^{-1}$  (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  $\text{sats s}^{-1} \rightarrow$  rate of accumulating *durable* energy claims.

Level 2 (Stock):  $S(T) = \int_0^T f(t) dt$  in  $\text{sats} \rightarrow$  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  $\text{sats s}^{-1}$ : 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  $\text{sats}$ . This omits durability adjustments. Optionally, discount by  $e^{-\rho t}$  for time preference.

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

**Scaling for readability.** Report  $\text{BXS}$  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
$BXS_{\text{core}}$	Size $\times$ Time (persistence)	Durability factors (A/I/SSR)	Neutral persistence
<b>BXS (durability)</b>	<b>Size <math>\times</math> Time <math>\times</math> HODLing <math>\times</math> Network <math>\times</math> Runway</b>	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

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

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,  $I_0 = 2.6 \times 10^{-10}$  s $^{-1}$ ; floors:  $t_{\min} = 10^3$  s,  $\mu_{\min} = 10^{-6}$  sats s $^{-1}$ .

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

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  $t_{\min}$ ,  $\mu_{\min}$  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:  $\text{HOLD} \sim W(t)$
  - M2:  $\text{HOLD} \sim W(t), A(t)$
  - M3:  $\text{HOLD} \sim W(t), A(t), I(t)$
  - M4:  $\text{HOLD} \sim W(t), A(t), I(t), \text{SSR}(t)$
  - M5 (full):  $\text{HOLD} \sim W(t), A(t), I(t), \text{SSR}(t), f(t)$

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  $\text{HOLD}=1$  if no net outflow beyond  $x\%$  over  $[t, t + \Delta]$  (e.g.,  $\Delta = 90$  days,  $x = 5\%$ ), else  $\text{HOLD}=0$ .
2. **Models:** Baseline logistic:  $\text{HOLD} \sim W(t), A(t)$ . Durability model:  $\text{HOLD} \sim W(t), A(t), f(t)$  (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  $\mu$  as large runway; optionally cap SSR at  $\text{SSR}_{\max}$  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 <sup>-1</sup> ]
$\mu(t)$	spending outflow [sats s <sup>-1</sup> ]
$A(t)$	value-weighted coin age (HODLing strength) [s]
$A_0$	coin-age baseline (e.g., rolling median) [s]
$I(t)$	protocol expansion rate [s <sup>-1</sup> ]
$I_0$	expansion-rate baseline [s <sup>-1</sup> ]
$s(t)$	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 <sup>-1</sup> ]
$S(T)$	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.

$$SSR(t) = \frac{s(t) + r i(t) - CP(t)}{\max\{t, t_{\min}\} \max\{\mu(t), \mu_{\min}\}}, \quad I(t) = \frac{\sigma(h(t))}{S(t)} \lambda(t),$$

$$f(t) = i(t) \cdot \frac{A(t)}{A_0} \cdot \frac{I(t)}{I_0} \cdot SSR(t), \quad S(T) = \int_0^T f(t) dt, \quad BXS(T) = \int_0^T S(t) dt.$$

## 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<sup>-1</sup>.
- Snapshot drivers (illustrative):  $A = 4.0 \times 10^8$  s;  $I = 3.0 \times 10^{-8}$  s<sup>-1</sup>;  $i = 1.0$  sats s<sup>-1</sup>;  $\mu = 1.0 \times 10^{-4}$  sats s<sup>-1</sup>;  $r = 2.0 \times 10^9$  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 Stacker (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  $\sigma, S, \lambda$  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  $t_{\min}, \mu_{\min}$ .
4. Evaluate  $f(t)$  each block interval; integrate numerically for  $S(T)$  and  $BXS(T)$ .
5. Report both  $BXS_{\text{core}}$  (size-only) and durability-aware  $BXS$ .