The Quantitative Ontology of Life:

A Flux-Based Framework and the Human Flux Unit (EFU)

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Foundations for a Flux-Based Metric of Living Systems**

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Abstract

Life is commonly described either through qualitative ontological categories or through fragmented quantitative measures such as mass, energy, or information. These approaches, while valuable, lack a unified framework that allows meaningful comparison across biological, ecological, and socio-technical systems.

This paper proposes a quantitative ontology of life, defining living systems not as static entities but as organized, sustained fluxes of matter, energy, and information maintained against entropic decay. Within this framework, existence is treated as a scalar and processual property rather than a binary state.

To enable cross-scale comparison, the paper introduces the Human Flux Unit (EFU) as a normalized reference unit grounded in empirically accessible human-scale fluxes. EFU is not proposed as a physical unit replacing SI measures, but as a comparative metric that enables consistent reasoning across heterogeneous systems.

The aim of this work is foundational: to establish ontological clarity, methodological boundaries, and a reproducible conceptual baseline upon which applied, empirical, and peer-reviewed studies may be built.

1. Introduction

1.1 The measurement problem of life

Despite significant advances in biology, ecology, and complex systems science, there remains no unified quantitative framework capable of comparing living systems across scales. Organisms, ecosystems, cities, and technologically extended life are typically analyzed using incompatible metrics, leading to conceptual fragmentation.

Three persistent limitations dominate current approaches:

1. Ontological fragmentation – life is split into biochemical, ecological, cognitive, and social domains without a shared quantitative foundation.
2. Metric incompatibility – physical, informational, and systemic measures cannot be directly compared.
3. Static bias – life is often treated as a substance or state rather than a sustained process.

These limitations restrict both comparative analysis and predictive capacity in an increasingly interconnected biosphere-technosphere system.

1.2 Aim and scope

This paper aims to:

- establish an ontological definition of life compatible with quantification,
- formalize life as persistent flux under constraint,
- introduce a normalized reference metric (EFU),
- explicitly delimit the scope, assumptions, and non-goals of the framework.

This work does not present a complete applied model or policy prescription. Its purpose is to provide a conceptual and methodological foundation suitable for open scientific critique and future empirical extension.

2. Ontological Premise

2.1 Life as sustained flux

We adopt the following ontological postulate:

A living system is a system capable of sustaining organized fluxes of matter, energy, and information over time against entropic dissipation.

In this view:

- identity is maintained through regulation rather than material persistence,
- boundaries are functional and dynamic,
- life is inherently non-equilibrium.

This aligns with systems ecology, non-equilibrium thermodynamics, and process-based biological theories, while remaining agnostic to metaphysical interpretations.

2.2 Quantitative ontology

A quantitative ontology is defined here as an ontological layer in which criteria of existence are expressible in measurable, comparable quantities.

This work does not attempt to resolve metaphysical ontology. Instead, it proposes an operational ontological layer that allows comparison between systems traditionally separated by disciplinary boundaries.

Within this framework:

- life is scalar, not binary,
- existence admits degrees and contextual thresholds,
- comparison becomes possible without category errors.

3. Hierarchical Flux Structure of Living Systems

Living systems are embedded in a multi-layer flux hierarchy, in which each level is characterized by dominant flux types and constraints:

Level

Description

Dominant flux

B

Biospheric

global material & energy cycles

A

Individual organism

metabolic flux

C

Cognitive system

information processing

D

Networked systems

social & technological flows

E

Temporal persistence

regulation over time

F

Physical limits

cosmological and thermodynamic constraints

Higher levels emerge from lower ones but are not reducible to them. The ontology is explicitly non-reductionist.

4. The Human Flux Unit (EFU)

4.1 Rationale

Humans occupy a mid-scale reference position:

- biologically complex,
- energetically measurable,
- socially embedded,
- empirically well-documented.

This makes human-scale flux an effective normalization baseline for comparative analysis.

4.2 Definition

1 EFU is defined as the normalized total sustained flux required to maintain one average adult human under baseline environmental and societal conditions over a standardized temporal window.

EFU is:

- not an SI unit,
- not a substitute for joules, kilograms, or bits,
- a comparative reference metric enabling ratio-based reasoning across heterogeneous systems.

4.3 Boundary conditions and scope

To ensure clarity and reproducibility, EFU is defined under explicit baseline assumptions:

1. Reference conditions – average adult human, standard physiological requirements.
2. Temporal window – standardized period (e.g., one year).
3. Included fluxes – metabolic, material, informational, and minimal societal support.
4. Excluded fluxes – luxury consumption, cultural excess, discretionary technological usage.

Explicit non-goals

EFU does not:

- define consciousness or moral value,
- prescribe policy outcomes,
- replace domain-specific physical measurements,
- claim universal invariance across contexts.

4.4 Toy example: minimal demonstrative application

System

Approximate EFU equivalents

Interpretation

Average adult human

1 EFU

Baseline

Small city (~50,000 people)

~50,000 EFU

Aggregated human-scale flux

Regional ecosystem

~100,000 EFU

Total biological throughput expressed in EFU terms

This example is illustrative, not predictive. Its purpose is to demonstrate comparability and methodological intent, not numerical precision.

5. Methodological Implications

EFU enables:

- cross-scale comparison between biological and technological systems,
- identification of systemic overload and sustainability thresholds,
- interdisciplinary dialogue without metric collapse.

EFU deliberately avoids:

- reduction of life to a single physical variable,
- normative or ethical claims,
- premature formal rigidity.

6. Causality and Consequences

6.1 Cause

The accelerating integration of biological life and technological systems demands a shared quantitative language capable of spanning multiple domains.

6.2 Effect

Without such a framework:

- sustainability claims remain rhetorical,
- systemic stress accumulates invisibly,
- comparisons across domains remain incoherent.

6.3 Consequence

A flux-based quantitative ontology allows earlier detection of systemic imbalance and supports reproducible interdisciplinary analysis.

7. Limitations and Future Work

- EFU requires empirical calibration across populations and environments.
- Applied models must specify contextual extensions.
- Independent replication and critique are essential.

These are requirements for maturation, not weaknesses.

8. Conclusion

This paper establishes a quantitative ontological foundation for understanding life as sustained flux. By introducing EFU as a normalized reference metric, it enables meaningful comparison across biological, ecological, and socio-technical systems without collapsing disciplinary distinctions.

The framework is intentionally open, inviting critique, refinement, and empirical testing.

Author’s Note

This work is presented as a foundational contribution. Applied case studies, formal mathematical extensions, and policy-relevant analyses are intentionally deferred to subsequent publications.