EFU ACADEMIC RESEARCH AUDIT v2.1

(English – Audit-Ready / Research Phase)

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Author: István Simor
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ABSTRACT

[HYPOTHESIS]
This document provides the methodological foundation of the EFU (Ecological Flux Unit / Human Flux Unit) research framework. The objective of the research is to test a universal biophysical reference unit based on human metabolic material and energy throughput, enabling comparison between technospheric and biospheric processes. The EFU is presented as a falsifiable theoretical construct rather than a finalized standard, intended for critical scientific evaluation and empirical refinement.

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1. CONCEPTUAL FOUNDATION AND RESEARCH LOGIC

[AXIOM]
According to the laws of thermodynamics and conservation of mass, the persistence of living systems depends not on static mass, but on continuous material and energy throughput.

[HYPOTHESIS]
Anthropocene-scale impacts are more accurately characterized by the intensity of flows (fluxes) rather than by accumulated stocks.

Research Definition – EFU Reference Unit

[PROTOCOL]
1 EFU is defined as **20 kg per day**, representing the average daily material throughput of an adult human organism.

Approximate composition:

- Air: ~15 kg/day
- Water: ~3 kg/day
- Food (dry + wet mass): ~0.5 kg/day

- Other materials (excretion, wear, trace matter): ~1.5 kg/day

[HYPOTHESIS]
An average human lifetime (80 years) corresponds to approximately **29,200 EFU**, equivalent to roughly **542 metric tons of cumulative material flux**.

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2. CONVERSION MODELS AND NORMALIZATION

[PROTOCOL]
Any measurable material or energy flow can be normalized into EFU units using time-based conversion.

Daily normalization:
EFU/day = (Total material flow in kg per day) / 20

Annual normalization:
EFU/year = (Total material flow in kg per year) / 7,300

Experimental Model-Level Comparisons

Process	Reported Material Flux	EFU-Equivalent (Model Value)
Coal-fired power plant	500,000 t/day coal	≈ 500,000 EFU/day
Global plastics production	400 Mt/year	≈ 55 million EFU/year
Danube sediment transport	10 Mt/year	≈ 1.4 million EFU/year
Humanity (8.1 billion people)	~60 Gt/year total flux	≈ 8.1 billion EFU (continuous)

Values are indicative and model-level, not regulatory claims.

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3. ARGUMENT MAP (LOGICAL STRUCTURE)

- **Premise A [AXIOM]:** All biological and socio-technical systems require continuous material flux to remain functional.
- **Premise B [HYPOTHESIS]:** A human-scale reference (20 kg/day) provides a meaningful universal normalization unit.
- **Conclusion C [HYPOTHESIS]:** EFU-based accounting reveals imbalances between anthropogenic throughput and biological regeneration capacity, enabling assessment of metabolic sovereignty.

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4. MODULAR RESEARCH STRUCTURE

[HYPOTHESIS] Mammalian Module
Scaling metabolic fluxes across mammalian species for comparative bioenergetics.

[PROTOCOL] Technosphere Module
Normalization of industrial, infrastructural, and digital systems (energy use, cooling water, material wear, waste) into EFU units.

[HYPOTHESIS] Planetary Module
Comparison of total human EFU flux with global biogeochemical cycles (e.g. Net Primary Production).

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5. EPISTEMOLOGICAL APPENDIX (EA)

Falsifiability Criteria

1. The EFU model is falsified if empirical population studies demonstrate that the 20 kg/day reference is not statistically representative of human metabolic throughput.
2. The framework loses explanatory value if EFU normalization shows no meaningful correlation with established biophysical indicators (e.g. exergy loss, entropy production, material flow analysis).

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6. CRITICAL COMMENTARY MATRIX

(Argument Map Audit)

Model Element	Critical Vulnerability	Recommended Research Direction
EFU reference (20 kg/day)	Oversimplification of demographic and climatic variance	Development of stratified EFU baselines
Material homogeneity	Equal mass treatment ignores thermodynamic quality	Entropy-weighted EFU components
Digital flux accounting	Indirect material effects difficult to quantify	ISO-aligned digital material flow models
Sovereignty gap concept	Regional regenerative capacity contested	Empirical bio-regional flux ceiling studies

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RESEARCH STATUS STATEMENT

EFU Academic Research Framework (2026 – Research Phase)
This framework and its quantitative assumptions remain open to critical scientific review, empirical testing, and methodological refinement. No regulatory or normative claims are implied at this stage.

Below is the full English version of

1. the 14-point academic footnote block, and
2. the Hungarian “Academic Note” translated to English in the same, stable style.

Mindkettőt önálló szekcióként tudod a dokumentum végére tenni.

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1. Fourteen-point academic footnote block (English)

1. The thermodynamic claim that the persistence of living systems depends on continuous energy and material throughput rather than on static mass is rooted in classical irreversible thermodynamics and non-equilibrium systems theory; modern readings of Schrödinger’s “What is Life?” explicitly describe organisms as structures maintained far from equilibrium by sustained flows.[pmc.ncbi.nlm.nih]
2. The 20 kg/day EFU reference point for human metabolism is supported in order of magnitude by empirical and guideline-based estimates of average adult water intake (typically 2–3 litres per day or around 30–40 ml per kg body weight), as well as by estimates of daily inhaled air volumes, which some sources place around 7,500 litres per day, corresponding to roughly 15 kg of air. When combined with food intake and metabolic by-products, these values broadly support the hypothesis of a ∼20 kg/day human material throughput, while still requiring population- and climate-specific calibration.pubmed.ncbi.nlm.nih+3
3. The lifetime estimate of approximately 542 metric tons of cumulative material flux and about 29,200 EFU over 80 years is a hypothetical extrapolation of the daily reference value. Substantial real-world variance (body mass, age, activity level, climate, health) implies that this remains a research-level parameter that should be tested and refined using representative population studies.
4. The core logic of the EFU framework – shifting the analytical focus from stock-based indicators to flux intensity – is conceptually aligned with material flow analysis (MFA) and related mass-balance-based methods, which increasingly describe anthropogenic systems in terms of flows and stocks bound by the law of conservation of mass. This perspective has become particularly relevant in interpretations of large-scale Anthropocene impacts.
5. The example of global plastics production on the order of 400 Mt/year is consistent with recent industry syntheses that place global plastics manufacturing above 410 Mt in 2023. Expressing such quantities in EFU is a model-level normalization for analytical and communicative purposes rather than a regulatory or legal assertion.[plasticsengineering]
6. Statements about the share of human biomass within global biomass draw on global biomass distribution studies, which highlight the dominance of humans and livestock relative to wild mammals. These findings support the research hypothesis that although the physical mass of humans is relatively small, the associated material and energy throughput – when expressed on an EFU scale – is comparable to major components of the biosphere.[rpgroup.caltech]
7. The hypothetical scaling rule in the mammalian module (metabolic flux as a function of body mass) connects to the broader literature on biological allometry, particularly

Kleiber's law, which describes resting metabolic rate as scaling with body mass approximately as B∝M3/4B \propto M^{3/4}B∝M3/4. The k-values used in the EFU framework are qualitative extensions of this relationship and require further species-level and life-stage-specific measurement.[arxiv]

8. The estimate of terrestrial Net Primary Production (NPP) in the range of ≈50–65 Gt C/year in the planetary module is grounded in empirical syntheses of global biogeochemical cycles, which place contemporary NPP within this interval while emphasizing significant uncertainty and methodological divergence. EFU-based normalization is a communicative and comparative analytical extension of this literature rather than a replacement.[rpgroup.caltech]
9. The terms "metabolic dignity" and "sovereignty gap" are internal concepts of the present research framework. "Metabolic dignity" is introduced as the hypothetical minimum level of human material and energy throughput required to sustain both biological and social functioning, while the "sovereignty gap" denotes the model-level difference (deficit or surplus) between a region's regenerative capacity and the anthropogenic material flux directed at it. Any normative content attached to these terms would require separate socio-legal and ethical analysis.
10. The intention of the "technosphere module" to express energy, cooling water, material wear, and waste flows in EFU units follows emerging research trends that seek to quantify the largely invisible material flows of digital and industrial systems (e.g. data centre energy and cooling water use, infrastructure abrasion). These trends are currently based on fragmented case studies and sectoral statistics, which justifies maintaining the explicitly hypothetical and preliminary status of the EFU framework.
11. The falsifiability criteria set out in the Epistemological Appendix – population-level statistical testing of the 20 kg/day reference, and examination of correlations between EFU normalization and established biophysical indicators (e.g. exergy loss, entropy production, material flow analysis) – codify a minimum standard of hypothesis testing in the philosophy of science sense. If the EFU metric fails to show meaningful relationships with established biophysical indicators, the explanatory power of the framework diminishes or may be lost altogether.
12. Approximating "digital flux" in EFU – especially the indirect material and energy requirements of data transmission, storage, and processing – is a complex measurement challenge that is not yet fully standardized under ISO or greenhouse gas (GHG) protocols. This motivates the recommendation in the audit text to develop ISO-aligned digital material flow models as a future research direction.
13. Empirically testing the "sovereignty gap" requires bio-regional studies of flux ceilings, linking the EFU framework to the literature on planetary boundaries and on local/regional resource-use limits. EFU is designed to be compatible with, but not a substitute for, such work: its purpose is to provide a human-scale flux normalization that, once calibrated, can be compared to bio-regional regenerative capacities.
14. For the document as a whole, EFU must be interpreted solely as a thought experiment and a research-phase pre-standard framework. The EFU values, conversion formulas, and modular applications presented are hypothetical tools for analytical and discursive purposes and cannot be regarded as regulatory, legal, or certification requirements in any form.

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2. "Academic Note on Biophysical Foundations" (English)

ACADEMIC NOTE ON BIOPHYSICAL FOUNDATIONS

This research document supports the Hungarian-language version of the EFU (Human Flux Unit / Ecological Flux Unit) framework, which operates as a human-scale reference unit defined on the basis of human material and energy throughput. The framework is explicitly in a research phase, presented as an open hypothesis rather than as any form of standardization or legal instrument.

The daily reference value of 20 kg/day per EFU is an order-of-magnitude estimate supported by typical adult patterns of water intake, air inhalation, and food consumption, while allowing for substantial demographic, health-related, and climate-dependent variability. The examples used in the document (global plastic flows, fuel throughput in power plants, riverine sediment, total human flux) are model-level, illustrative normalizations and must not be interpreted as regulatory or certification.

The EFU framework is related to research on socio-economic metabolism and material flow analysis (MFA) in industrial ecology, which models socio-economic systems using mass-balance-consistent descriptions of stocks and flows grounded in the law of conservation of mass. EFU does not replace these methods; instead, it proposes a human-scale, communicative, and comparative normalization that remains falsifiable and calibratable against existing MFA, exergy, and entropy-production indicators.oaepublish+3

The terms “Fluxus”, “Metabolic Dignity”, “Sovereignty Gap”, and “Audit” are specific, internally defined concepts of the present EFU research framework. They are not evaluative or legal categories, but analytical constructs intended to make human-scale material and energy flows, and the relations between technosphere and biosphere, more transparent for empirical investigation and critical assessment.