

EFU-WATER FRAMEWORK v2.1 – RESEARCH AUDIT EDITION

Experimental Research Framework (Pre-standard)

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ABSTRACT

[AXIOM] Under the physical law of conservation of water, total water quantity in the Earth system is effectively constant, while its **quality**, spatial distribution and timing are continuously reconfigured by natural and human processes.[news.climate.columbia+1](#)

[HYPOTHESIS] The EFU-WATER research model proposes an ISO-14046-compatible, biophysical accounting logic that projects global and regional water-use data onto a human-scale reference of 1 000 litres per capita per year, used purely for communication and normalization purposes.[iso+1](#)

[HYPOTHESIS] The experimental base unit 1 EFU-W = 1 000 L/capita/year is not a consumption quota but a flux-normalization anchor designed to make water flows and water-footprint indicators comparable across sectors, regions and scenarios.

[HYPOTHESIS] EFU-WATER integrates planetary metabolic flows – especially the coupled water ↔ carbon ↔ nutrient (N, P) cycles – into an open, LCA-based computational model that can later converge towards standardization, without prescribing legal thresholds at this phase.[scenariutc.utc+1](#)

[PROTOCOL] This document explicitly records a research-phase framework whose purpose is not water law or permitting, but a biophysical accounting layer that supports SDG 6, planetary freshwater boundaries and the biogeochemical grounding of water crediting schemes.[iso-library+1](#)

This document represents an ongoing research construct; all models and thresholds are provisional and subject to revision or falsification.

“A TUDÁS AZ, MI FELEMEL” – EFU-WATER is intended to make water-use decision-making more transparent, more just, and better aligned with the limits and dynamics of natural systems.

0. Research Status and Scope

[HYPOTHESIS] Water mass and energy flows can be brought to a common denominator through a per capita flux model (1 000 L/capita/year), enabling comparability between global, regional and local systems.[\[scenariutc.utc\]](#)

[HYPOTHESIS] Per capita normalization in EFU-W units is suitable for putting water-use and water-footprint indicators from different LCA studies onto a comparable scale, irrespective of sector or technology.[\[iso-library\]](#)

[PROTOCOL] EFU-WATER is not a legal, permitting or compliance tool, but a biophysical accounting layer that takes ISO-14046 water-footprint outputs (water use, scarcity, quality-related impacts) and normalizes them into EFU-W units.[\[standards.iteh+2\]](#)

[PROTOCOL] The framework is designed to:

- enhance comparability of water-use and water-footprint indicators,
- support biogeochemical grounding of water-credit systems,
- and provide a bridge between planetary freshwater limits and practical decision-making at project, corporate, urban and basin scales.[\[news.climate.columbia+2\]](#)

[PROTOCOL] EFU-WATER is recommended **only** where an ISO-14046-compatible water footprint assessment already exists; it complements, and does not replace, the underlying ISO-based study.[\[iso+2\]](#)

Indicative use-cases

[PROTOCOL]

- Normalizing ISO-14046 water-footprint results from multiple case studies to a shared EFU-W scale to enable communication and comparison across products, services, regions and time horizons.[\[iso+1\]](#)
- Calibrating water credits and compensation mechanisms in EFU-W units, while explicitly reflecting biogeochemical fluxes and local scarcity conditions.[\[essd.copernicus+1\]](#)
- Providing EFU-based, per capita normalization for interpreting SDG 6.4 indicators (water-use efficiency, water stress) in relation to planetary freshwater boundaries.[\[scenariutc.utc+1\]](#)

I. Reference Definition and Coupling Structure

[AXIOM] Water used in human and natural systems eventually re-enters the hydrological cycle (via evaporation, runoff, infiltration, reuse), but not necessarily in the same **quality**, place or time; therefore, volumetric equality does not imply environmental equivalence.[\[news.climate.columbia+2\]](#)

[HYPOTHESIS] The human-scale reference of 1 000 L/capita/year can serve as a stable normalization point for communication across heterogeneous water-use domains (agriculture, industry, households, ecosystem services).

EFU reference table (experimental configuration)

Symbol	Element	EFU reference	Note
EFU-W	Water	1 000 L/capita/year	Normalization reference
EFU-C	Carbon	7.3 t CO ₂ /capita/year	Carbon anchor
EFU-N	Nitrogen	16 kg N/capita/year	Nitrogen coupling
EFU-P	Phosphorus	0.55 kg P/capita/year	Phosphorus link

[HYPOTHESIS] These EFU references place water, carbon and nutrients on a shared, human-scale axis, supporting joint interpretation of planetary boundaries and micro-level choices (individual, corporate, urban).[news.climate.columbia+1](#)

[HYPOTHESIS] Current estimates of global blue-water withdrawals of roughly 3 000–4 000 km³/year, with a proposed planetary boundary around 4 000 km³/year, can be translated into EFU-W per capita, making aggregate water pressure comparable to the EFU-C carbon reference of 7.3 t CO₂/capita/year.[scenariutc.utc+1](#)

[HYPOTHESIS] Through EFU-N and EFU-P, water–nutrient relationships – especially eutrophication risks and irrigation-driven nutrient flows – can be integrated into a common flux balance that links hydrological, agricultural and ecological processes.[pdfs.semanticscholar+2](#)

Conceptual triad description

[HYPOTHESIS] EFU-WATER operates within a water–carbon–nutrient triad, where EFU-W represents water flows, EFU-C represents fossil and biogenic carbon fluxes, and EFU-N/P capture fertilizer- and wastewater-related nutrient loads, all expressed in EFU units to maintain communicable, human-scale metrics.[iso-library+2](#)

ARGUMENT MAP – EFU-WATER flux logic

[ARGUMENT MAP]

- A: Water use shapes all other major biophysical fluxes (energy, nutrients, biomass), because water is the main carrier, solvent and transport medium in the Earth system and in socio-economic metabolism.[news.climate.columbia+1](#)
- B: Human-scale normalization (EFU-W = 1 000 L/capita/year) supports cross-sector and cross-region comparability and translates technical indicators into scales intelligible to decision-makers and the public.[iso-library+1](#)
- C: EFU-WATER therefore allows water use to be partly decoupled from legal categories and reframed as a biophysical ledger that can be interpreted jointly with EFU-C, EFU-N and EFU-P within a planetary-boundary-aware governance framework.[scenariutc.utc+2](#)

Derivation:

[ARGUMENT MAP] A + B → C

II. ISO-14046 Compatibility (Methodological Layer)

[PROTOCOL] EFU-WATER is explicitly grounded in ISO-14046 water-footprint assessment: it preserves the underlying impact logic (LCA-based, spatially and temporally explicit, scarcity- and quality-sensitive), and adds a human-scale normalization layer.[standards.iteh+2](#)

[PROTOCOL] Experimental EFU-WATER indicator definition:

$$\boxed{\text{EFU-}} \\ \boxed{\text{WATER} = 1000 \text{L/capita/year} \times \text{Water Use} \times \text{Scarcity Factor} \times \text{Quality Impact}}$$

where:

- Water Use: volumetric water use or consumption as defined in the underlying ISO-14046 study (e.g. m³ or m³ eq along the life cycle).[standards.iteh+2](#)
- Scarcity Factor: spatially and temporally specific water-scarcity characterization factor (e.g. AWARE midpoint indicator), typically at watershed and monthly scale or an appropriate aggregated resolution.[wulca-waterlca+1](#)
- Quality Impact: characterization factor for water-quality-related environmental impacts (eutrophication, ecotoxicity, salinization, thermal pollution, etc.) consistent with the LCA method selected.[standards.iteh+1](#)

[PROTOCOL] The sources, versions and resolutions of Scarcity Factor and Quality Impact must be explicitly documented in every EFU-WATER application (database, year, geographic coverage, temporal resolution) to ensure comparability and reproducibility.[wulca-waterlca+2](#)

[HYPOTHESIS] EFU-WATER can serve as a translation layer that allows water-footprint results derived from different LCA methods and databases to be interpreted on a common per capita EFU scale, improving communication, policy application and credit-based mechanisms.[iso-library+1](#)

[PROTOCOL] When reporting EFU-WATER outcomes, practitioners are encouraged to specify at least:

- system boundaries of the assessed product, service or region,
 - type of water use (withdrawal, consumption, return flows),
 - selected scarcity and quality models (e.g. AWARE version X, method Y for quality impacts),
 - spatial and temporal resolution of inputs and characterization factors.[wulca-waterlca+2](#)
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III. Scope and Limitations (Non-normative Clauses)

[PROTOCOL] EFU-WATER is a research-phase, non-normative framework intended for analytical, educational and exploratory policy support; it is not a legally binding standard, nor is it sufficient on its own for permitting or regulatory compliance.

[PROTOCOL] EFU-WATER does not replace ISO-14046 water-footprint assessment; it assumes that such an assessment has been performed and only normalizes and re-expresses its outputs in EFU-W terms.[iso+2](#)

[PROTOCOL] EFU-WATER does not define an independent “safe operating space” for water use; instead, it aims to support interpretation against existing planetary freshwater boundaries (e.g. ~4 000 km³/year blue water consumption) and basin-scale thresholds.[news.climate.columbia+1](#)

[HYPOTHESIS] Per capita EFU normalization may help reveal distributional justice issues, access inequalities and regional water-stress patterns, but is not, by itself, a prescriptive allocation mechanism for determining who may use how much water.[\[scenariutc.utc\]](#)

IV. Citation Suggestion

[PROTOCOL] Suggested citation format (example):

Simor, I. (2026). **EFU-WATER FRAMEWORK v1.1 – Experimental Research Framework (Pre-standard).** EFU Research Phase Document, EFU-A/WATER-2026-01-R01.

EA – Epistemological Appendix

EA.1 Falsifiability

[HYPOTHESIS] The EFU-WATER framework is falsifiable at multiple levels:

- If empirical evidence robustly shows that the 1 000 L/capita/year reference does not function as a stable or meaningful normalization point (e.g. it systematically distorts specific regions or sectors), the EFU-W scaling requires revision.[\[scenariutc.utc\]](#)
- If improved hydrological and LCA models demonstrate that the selected scarcity and quality factors (e.g. AWARE) do not capture water-deprivation and ecosystem-impact dynamics adequately, EFU-WATER outputs would be systematically biased and the protocol must be updated.[wulca-waterlca+1](#)
- If new global freshwater-use data imply a significant re-evaluation of planetary freshwater boundaries (e.g. moving beyond the ~4 000 km³/year reference), the interpretation of EFU-WATER indicators relative to these boundaries must be revisited.[news.climate.columbia+1](#)

[PROTOCOL] To support falsification and learning, each EFU-WATER application is encouraged to:

- record data sources, LCA models and versions used,
- perform sensitivity analyses on scarcity and quality factors,
- compare per capita EFU-W results with alternative normalization choices (e.g. GDP-based, land-area-based, ecological footprint based).[standards.iteh+1](#)

EA.2 Uncertainty Factors

[HYPOTHESIS] EFU-WATER results inherit and combine uncertainties from several domains that require explicit handling:

- Data uncertainty: limitations and errors in water-use statistics, hydrological models and LCA databases, including gaps in regional coverage and temporal detail.[waterfootprint+2](#)
- Model uncertainty: structural differences and assumptions across water-scarcity and impact models (e.g. AWARE vs. alternative approaches), including choices of temporal and spatial aggregation.[wulca-waterlca+1](#)
- Spatio-temporal variability: strong seasonal and inter-annual fluctuations in water availability and demand (droughts, floods, climatic shifts), and the way these are aggregated in EFU-WATER calculations.[iso-library+1](#)
- Normative uncertainty: concepts such as “fair share” and “equitable water allocation” depend on social and political choices; EFU-WATER does not prescribe such norms but aims to provide a transparent, biophysical baseline for those debates.

[PROTOCOL] Each EFU-WATER-based publication or report should include a brief uncertainty section, explicitly discussing at least data and model uncertainties, and where possible, quantifying their influence on EFU-WATER results.[standards.iteh+1](#)

AI Disclosure Statement

AI Usage Disclosure: This research framework was developed with the strategic assistance of Artificial Intelligence (Large Language Models). AI was utilized as a precision tool for structural optimization, cross-referencing ISO standards, and formalizing logical connections between biophysical flux modules. While the AI facilitated analytical consistency and linguistic refinement, the core conceptual architecture, the EFU-normalization logic, and the final expert validation were exclusively authored and directed by the human researcher, István Simor (EU Independent Expert EX2026D1342540). This collaboration represents an intentional "Human-AI Partnership" to enhance scientific clarity and systemic integration.