Appendix A.

Energy-Cognitive Equivalent (IEKV): Definitions and Formulae**
(Translated according to the standard rules; formulas preserved)

1) Basic Definitions

Let the computational window be defined as
$t \in [t_0, t_1]$,
and let P denote a system, process, or product.

The IEKV is treated in vector form:

$$\mathrm{IEKV}(P,t) = \left(\Delta E_{\mathrm{sys}},\ \Delta S_C,\ \Delta S_A,\ \Delta E_{\mathrm{upr}}\right)$$

Additional term: the management-related energy footprint ΔE_{upr}

To compute IEKV, an additional component is introduced:

$$\Delta E_{\mathrm{upr}} = E_{\mathrm{data}} + E_{\mathrm{alg}} + E_{\mathrm{comm}} - E_{\mathrm{opt}},$$

where we account for the energy spent on data processing, algorithmic computation, and communication, **minus** the resource-optimization effect.

This ensures internal self-verification of the model through the criterion
$\mathbf{EROI_{governance} \geq 1}$
(the *Principle of Energetic Consistency*).

2) Energetic Component ΔE_{sys}

2.1. Full Marginal Energy Costs with Corrections

$$\Delta E_{\mathrm{sys}} = E_{\mathrm{oper}} + E_{\mathrm{emb}} + E_{\mathrm{trans}} + E_{\mathrm{maint}} - E_{\mathrm{bench}}$$

2.2. Exergy and Environmental Adjustments

$$\Delta E^*_{\mathrm{sys}} = \Delta E_{\mathrm{sys}} - \lambda_{\mathrm{ex}} \cdot \mathrm{ExLoss} - \lambda_{\mathrm{eco}} \cdot \mathrm{EcoPenalty}$$

2.3. Energetic Result of the Process (sign matters)

$$\Delta E_{\mathrm{out}} = E_{\mathrm{bench}} - E_{\mathrm{real}}$$

A positive value indicates that the system *saves* energy relative to its benchmark.

2.4. Normalisation to a Reference Standard (for comparability)

$$\hat{E} = \frac{\Delta E^*_{\mathrm{sys}}}{E_{\mathrm{ref}}}$$

3) Human Entropy–Cognitive Contribution ΔS_C

Concept: to evaluate the increase of information or meaning contributed by a human agent as a *reduction of uncertainty* and an *increase in the originality of knowledge integration*.

3.1. Reduction of Semantic Uncertainty

$$\Delta S_C^{(1)} = H_{\text{prior}} - H_{\text{post}}$$

3.2. Novelty of Integration

(not bit-volume, but *semantic originality*)

$$\Delta S_C^{(2)} = \text{Novelty\_semantic}$$

(e.g., divergence from baseline corpora)

3.3. Integrativity (cross-domain synthesis)

$$\Delta S_C^{(3)} = \text{CrossDomainIntegrationIndex}$$

3.4. Final Index of Human Cognitive Entropy

$$\Delta S_C = w_1 \Delta S_C^{(1)} + w_2 \Delta S_C^{(2)} + w_3 \Delta S_C^{(3)}$$

4) Algorithmic / AI Entropy Contribution ΔS_A

The informational gain produced by algorithms is evaluated **separately from the human component**.

4.1. Informational Gain of the Model (update divergence)

$$\Delta S_A^{(1)} = D_{\text{KL}}\left(M_{\text{new}} \parallel M_{\text{old}}\right)$$

4.2. Solution Novelty (algorithmic non-stereotypicality)

$$\Delta S_A^{(2)} = \text{AlgorithmicNoveltyScore}$$

4.3. System-Level Effect (reduction of technological entropy)

$$\Delta S_A^{(3)} = \text{TechEntropy}_{\text{before}} - \text{TechEntropy}_{\text{after}}$$

4.4. Final Index of Algorithmic Entropy

$$\Delta S_A = v_1 \Delta S_A^{(1)} + v_2 \Delta S_A^{(2)} + v_3 \Delta S_A^{(3)}$$

5) Aggregation into the IEKV Profile and (Optionally) Scalarisation

5.1. Profile (baseline reporting format)

$$\text{IEKV}(P,t) = \left(\hat{E},\ \Delta S_C,\ \Delta S_A,\ \Delta E_{\text{upr}}\right)$$

5.2. Optional: One Scalar Metric (for dashboards)

$$\mathrm{IEKV}_{\mathrm{scalar}} = \alpha \hat{E} + \beta \Delta S_C + \gamma \Delta S_A - \delta \Delta E_{\mathrm{upr}}$$

6) CEC Verification Loops (Operationalisation)

- **LCA boundaries** (*Life-Cycle Assessment*) are published prior to the computation; embedded energy E_{emb} is calculated according to approved catalogues.
- **Semantic entropy and novelty** are computed against a public corpus (*Data Commons*); models and code are stored in an open registry.
- **Zero Bias:**
  weight coefficients *w*, *v* and normalisation procedures are fixed *ex ante* by domain; annual fairness audit is mandatory.
- **Appeals:**
  the author/team may contest ΔS in the cognitive appellate court;
  recalculation with alternative semantic metrics is permitted.
- **Ethical Threshold:**
  decisions with high $\mathrm{IEKV}_{\mathrm{scalar}}$ **but** with demonstrated risk of reducing cognitive autonomy
  (CEC flag) are rejected
  (*Axiom of Predictive Humanism*).