A Constraint–Relaxation Energy Model:
Interaction-Dependent Emergence of Energy from Structured Information

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Abstract

This paper presents the **Constraint–Relaxation Energy Model (CREM)**, a theoretical framework proposing that energy is an emergent consequence of imposing and relaxing constraints on an underlying phase space of possible states. Building on established principles from thermodynamics, information theory, and systems science, CREM reframes energy as the release of compressed geometric and informational relationships rather than a primitive substance. The model integrates feedback, coherence, and constraint geometry as necessary conditions for stable energy storage and release. Speculative extensions are explicitly delineated from established physics, positioning CREM as a unifying interpretive framework rather than a claim of new empirical phenomena.

1. Introduction

Energy is traditionally treated as a fundamental quantity conserved across physical processes. However, developments in information thermodynamics and systems theory suggest that energetic phenomena may be more deeply understood as emergent from structural constraints imposed on degrees of freedom. The Constraint–Relaxation Energy Model (CREM) formalizes this perspective by proposing that energy corresponds to the release of relational structure formed when constraints reduce available state space.

2. Theoretical Background

2.1 Constraints and Degrees of Freedom

In physics, constraints define allowable configurations of a system. Reducing degrees of freedom increases structure, order, and potential work capacity. This principle underlies mechanical, electromagnetic, chemical, and nuclear energy systems.

2.2 Information and Thermodynamics

Landauer’s principle demonstrates that information processing has energetic consequences. Similarly, Shannon entropy quantifies uncertainty reduction. CREM interprets these results geometrically: information corresponds to constrained relational structure.

3. The Constraint–Relaxation Energy Model

CREM defines energy as an emergent property arising from three conditions:

- **Constraint Imposition** – reduction of degrees of freedom
- **Metastable Maintenance** – sustained via feedback
- **Controlled Relaxation** – release of

relational structure

Energy does not originate from nothing; it reflects the relaxation of imposed structure.

4. Formal Description

Let:

P = unconstrained phase space

C = set of constraints

$D(P)$ = degrees of freedom

G = induced relational geometry

Constraint condition: $D(P|C) < D(P)$

Stored energy: $E_s \propto D(P) - D(P|C)$

Released energy: $E_r \propto -dG/dt$

Feedback condition: Stability exists only if constraint decay ≤ feedback reinforcement.

5. Relation to Existing Energy Systems

CREM subsumes known energy mechanisms as special cases, including elastic systems, capacitors, lasers, chemical reactions, and nuclear processes. Each operates by imposing constraints and harvesting energy during relaxation.

6. Speculative Extensions

CREM hypothesizes that deeper informational constraints—beyond known physical boundary conditions—may exist. These extensions remain theoretical and require future empirical validation.

7. Discussion

CREM offers a unifying conceptual framework linking energy, information, and structure. By emphasizing constraints rather than substances, the model provides a coherent language bridging physics, computation, and complex systems.

8. Conclusion

Energy may be most fundamentally understood as the dynamic release of structured relational geometry imposed on possibility space. CREM formalizes this insight while maintaining strict consistency with known physical laws.

References

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Figure Descriptions (Textual)

Figure 1. Constraint imposition reducing phase-space degrees of freedom.

Figure 2. Feedback-stabilized constraint loop enabling energy extraction.

Figure 3. Constraint relaxation releasing stored relational structure.

PHASE 3

Mathematical Appendix (Refined Formalism)

Appendix A: Constraint Geometry Formalism

Let S be a system with state vector $x \in P$.
Define constraint operator: $C(x) \rightarrow x' \in P\_C$
Entropy reduction: $\Delta S = k \cdot \ln[D(P) / D(P\_C)]$
Energy equivalence: $E \geq T \cdot \Delta S$

Where:

- T is effective system temperature
- Energy reflects the work potential of reduced state accessibility

Appendix B: Feedback Stability Condition

Let F be a feedback function maintaining C.
Stability requires: $\partial C/\partial t + \partial F/\partial t \geq 0$
Failure leads to rapid decoherence and loss of stored structure.

Appendix C: Generalized Energy

Statement

Energy is not fundamental but derivative:
$E \equiv \int(\text{Constraint Density} \times \text{Relaxation Rate})\, dV$

This formulation recovers classical energy expressions under appropriate boundary conditions.