

The Human Engine: A Conceptual Framework of Sky–Earth Flows in Coupled Human–Natural Systems.

Putri Nurgis Alita

Argael Publisher, Medan, Medan 20255, Indonesia

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

<https://doi.org/10.70471/7ds4dc03>

Received: 19/2/2026

Published: 28 /2/2026

Original Research Article

Abstract

This article proposes *The Human Engine* framework as a conceptual model for understanding humans as a processing nexus that transforms vertical flows of energy and information between "sky" (atmospheric and informational inputs) and "earth" (material and institutional substrates) within coupled human–natural systems. Using a transparent narrative literature review, we synthesized 28 peer-reviewed studies and theoretical articles on coupled human–natural systems (CHANS), human–Earth system interactions, and systems thinking published between 2007–2025, retrieved from Scopus, Web of Science, and Google Scholar. The review identifies a theoretical gap: existing models typically position humans as aggregate economic or biogeophysical actors, but rarely conceptualize them as internal "engines" that process vertical sky–earth inputs into socio-ecological outputs. The proposed framework introduces five core components—*Sky Input Flow* (energy, climate signals, knowledge, values), *Sky Output Flow* (emissions, technology, narratives), *Earth Grounded System* (ecosystems, infrastructure, institutions), *Core Human Engine Nexus* (biological, psychological, social processing subsystems), and paired *Upward Vectors* (transformational tendencies toward awareness and long-term orientation) and *Downward Vectors* (grounding pressures from material needs and constraints). Three testable propositions link these components: (1) high-quality Sky Input

Corresponding author: putrialita45@gmail.com

Cite as: Alita, P.N. (2025). *The human engine: A conceptual framework of sky–earth flows in coupled human–natural systems*. *Asian Multidisciplinary Research Journal of Economy and Learning*, 3(2), 14–26. <https://doi.org/10.70471/7ds4dc03>

strengthens Upward Vector when Earth Grounded pressure is manageable; (2) excessive Earth pressure strengthens Downward Vector, driving short-term adaptive choices; (3) Upward/Downward balance determines system trajectory toward regenerative or destructive pathways. This heuristic framework offers diagnostic utility for sustainability policy, education, and organizational practice, and provides a foundation for empirical hypothesis testing and dynamic modeling of transformative sustainability transitions.

Keywords: Human Engine, conceptual model, coupled human–natural systems, systems thinking, sky–earth flow, sustainability transition, human–Earth system interactions.

1. INTRODUCTION

The Anthropocene era marks a time when human activity has become a dominant force reshaping Earth's climate, biodiversity, and biogeochemical processes at planetary scale (Rockström et al., 2009). This reality renders sectoral approaches that separate humans from the environment increasingly inadequate. Social and ecological systems must be understood as dynamic, interconnected wholes rather than isolated domains (Rockström et al., 2009). Within this framing, humans should be viewed as a structural component of the Earth system, not merely an external pressure source.

The *coupled human–natural systems* (CHANS) framework positions humans and nature as integrated systems with bidirectional interactions (Liu et al., 2007). Changes in the social dimension are intrinsically linked to biophysical dimensions such as hydrology, land use, and ecosystem function (Liu et al., 2007). This approach emphasizes feedback loops, time lags, and thresholds in socio-ecological systems. However, humans are often represented in aggregate form—sectors, regions, or demographic units—without depicting the internal dynamics that make humans active drivers of system behavior (Liu et al., 2007).

The study of *human–Earth system interactions* integrates economic, energy, land-use, and climate models to analyze the interplay between human activities and Earth processes (Prinn, 2013). This integrative approach is essential for policy scenario formulation and long-term risk assessment (Prinn, 2013). Yet humans are typically modeled as energy demand modules or emission sources, under-representing dimensions of experience, consciousness, and meaning-making. This reductive representation limits understanding of how human decisions actively shape system trajectories.

Systems thinking offers a perspective emphasizing relationships among parts, feedback patterns, and whole-system behavior rather than isolated components (Meadows, 2008). In sustainability contexts, this approach helps policymakers consider indirect and cross-scale consequences (Meadows, 2008). Social and ecological systems are understood as networks of interconnected processes. This framework opens conceptual space for models that center humans as processors of energy and information flows, not merely passive recipients or linear consumers (Wamsler & Restoy, 2020).

Recent literature demonstrates that CHANS modeling continues to face challenges in integrating scale, difficult-to-measure social variables, and long-term uncertainty (Li et al., 2023). Many models emphasize material aspects such as energy flows and land-cover change, while human values and motivations are reduced to economic indicators (Liu et al., 2007). The predominant focus is also on horizontal flows between sectors or regions, rather than vertical flows connecting energy and information sources with material substrates. These limitations underscore the need for a richer, more reflexive conceptual framework.

The concept of planetary boundaries illustrates that human activity has approached or exceeded several critical ecological thresholds (Rockström et al., 2009). Pressure at one boundary can amplify pressure at others, narrowing the safe operating space for humanity (Rockström et al., 2009). This situation demands better understanding of how life choices and collective values contribute to the accumulation of these pressures. The integration of

ethical and conscious dimensions into systems frameworks is increasingly recognized as urgent (Wamsler & Restoy, 2020).

CHANS science emphasizes mapping feedback loops between landscape patterns, ecological processes, ecosystem services, and human well-being to support sustainability policy (Liu et al., 2007). However, the relationship between human internal states—cognition, affect, motivation—and responses to environmental signals is rarely explicitly modeled (Li et al., 2023). Collective decisions are rooted in meaning-making and decision processes at individual and group levels. Conceptualizing humans as "engines" that process environmental inputs into social action can bridge micro- and macro-scales.

Various knowledge traditions depict humans as a link between heaven and earth, through spiritual and ecological metaphors (Hubbard, 2016). In contemporary scientific readings, "sky" can symbolize the source of energy, information, and uncertainty, while "earth" represents material substrate and ecological boundaries (Hubbard, 2016). Humans occupy the interface of the two, receiving, filtering, and transforming these flows. This vertical metaphor is relevant for developing the *Sky–Earth Flow* model, positioning humans as the nexus of the system.

The development of human–Earth interaction models typically begins with system architecture sketches mapping components, flows, and feedback loops before mathematical formalization (AIMES Project, 2022). Such frameworks connect economic, energy, and climate modules into integrated systems. The *Human Engine* diagram can be positioned as a micro-system architecture centering human roles. Vectors such as *Sky Input Flow*, *Sky Output Flow*, *Upward Vector*, and *Downward Vector* represent the direction and intensity of flows processed by the human engine core.

Recent studies emphasize that the future of CHANS research requires enriched theories and methodologies capable of capturing the complexity of human–nature relationships (Li et al., 2023). Modeling should incorporate material, informational, institutional, and value dimensions in more balanced ways (Liu et al., 2007). This article addresses this need by proposing *The Human Engine* framework as a conceptual model positioning humans as processing machines of vertical flows between sky and earth. This model is expected to serve as a foundation for developing more holistic hypotheses and dynamic models in the study of human–environment systems (Rockström et al., 2009; Liu et al., 2007).

2. METHODS

2.1 Research Design

This article is a conceptual/theoretical paper focused on developing a model framework through narrative literature synthesis, without collecting new empirical data. This approach aligns with scholarly standards recognizing theory-driven papers as legitimate contributions when authors develop new conceptual positions based on synthesis of existing theories[9]. The methods section remains detailed so that the model development process can be replicated or extended by other researchers.

2.2 Narrative Literature Review Approach

The *Human Engine* framework was developed through an interpretive narrative literature review emphasizing in-depth theoretical understanding rather than quantitative mapping of all available studies. The narrative approach was selected because it provides greater flexibility in integrating cross-disciplinary literature spanning CHANS, human–Earth systems, systems thinking, and sky–earth metaphors in ecology and sustainability education.

2.3 Literature Search and Selection Protocol

A systematic literature search was conducted in three major academic databases (Scopus, Web of Science, and Google Scholar) between January 2007 and January 2025. This 18-year window captures foundational CHANS literature (Liu et al., 2007) through contemporary systems thinking and planetary boundaries updates.

Search strings: Core keyword combinations included:

- "coupled human–natural systems" OR "coupled human–nature systems" OR "CHANS"
- "human–Earth system interactions" OR "human–Earth system modeling"
- "systems thinking" AND "sustainability"
- "sky–earth" OR "heaven–earth" AND ("ecology" OR "sustainability" OR "environment")

Inclusion criteria:

1. Peer-reviewed journal articles, book chapters, or authoritative reports
2. Incorporates human–environment systems framework, models human–Earth interactions, or applies systems thinking to sustainability
3. Published in English
4. Contains theoretical or conceptual content relevant to system components, flows, or feedback

Exclusion criteria:

1. Purely descriptive case studies without systemic analysis
2. Technical reports without theoretical framing
3. Publications lacking clear systems dimensions

Initial searches yielded 147 candidate sources. After title and abstract screening, 52 sources met inclusion criteria. Full-text review focused on extracting core concepts related to system components, flow types, and feedback patterns relevant to human–nature relationships. Final synthesis incorporated 28 sources that provided theoretical foundations for model components (see Table 1).

Selected articles were cross-referenced with citation lists from major CHANS and human–Earth system reviews to ensure key influential publications were not overlooked. Methodological decisions—keywords, selection criteria, inclusion/exclusion logic—were documented as an audit trail to ensure transparency and reproducibility (Sukhera, 2022).

2.4 Literature Analysis and Synthesis

The analysis phase involved full-text reading of selected articles and extraction of core concepts related to: (i) system components (what constitutes the system), (ii) types of flows (energy, matter, information, values), and (iii) feedback patterns (bidirectional causality, time lags, thresholds). Concepts were grouped thematically into three clusters: "system structure," "feedback dynamics," and "meaning/consciousness dimensions".

Extracted concepts were then mapped to elements in the preliminary *Human Engine* diagram to identify theoretical correspondences and gaps. This mapping served as the foundation for developing operational definitions of model components such as *Sky Input Flow*, *Earth Grounded System*, *Upward Vector*, and *Core Human Engine Nexus*.

2.5 Conceptual Model Development Process

Model development proceeded iteratively through three main steps: (1) mapping literature concepts to diagram elements, (2) refining relationships among components, and (3) formulating theoretical propositions linking sky–earth flows to human responses. Each revision cycle examined whether the model structure remained consistent with systems thinking principles such as interconnections, feedback, and adaptive dynamics as reviewed in systemic sustainability studies (Meadows, 2008; Hörisch et al., 2025).

The development process is summarized in a methodological flow: literature identification → concept codification → initial model construction → refinement through theoretical consistency checks. This iterative process ensured that the model was grounded in established theory while offering novel integrative value.

2.6 Methodological Limitations and Validity

As a narrative review, this synthesis reflects conceptual judgment and is subject to potential selection bias, despite transparency measures. The review did not follow a full systematic review protocol (e.g., PRISMA), limiting claim strength regarding comprehensiveness. The model remains at a heuristic stage without mathematical formulation or operational indicators.

To enhance reliability, selected articles were cross-checked against reference lists of major CHANS and human–Earth system reviews (Liu et al., 2007; Li et al., 2023). An audit trail documents search keywords, selection criteria, and inclusion/exclusion rationale. The model's theoretical propositions are formulated to be testable, inviting empirical validation.

3. RESULTS AND DISCUSSIONS

3.1 Thematic Synthesis of Literature

The literature review yielded three main thematic clusters:

Cluster 1: Coupled Human–Natural Systems (CHANS) and Human–Earth System Interactions

This cluster emphasizes interconnections and feedback between social and ecological systems. Human representations tend to be aggregative, focusing on material variables such as land use, resource extraction, and emissions. Internal human processes—cognition, motivation, values—are under-represented (Liu et al., 2007; Li et al., 2023).

Cluster 2: Systems Thinking Approaches to Sustainability

This cluster emphasizes relationship patterns, feedback loops, and whole-system behavior rather than isolated components. Systems thinking helps identify leverage points for intervention and anticipate cross-scale consequences. However, few models visualize humans as vertical nexuses connecting energy/information sources with material boundaries.

Cluster 3: Vertical Sky–Earth Metaphor

Various traditions depict humans as bridges between "heaven" (energy, information sources) and "earth" (material substrate, ecological boundaries). Contemporary interpretations position humans at the interface, receiving, filtering, and transforming these flows. This metaphor has not been formalized into a systemic model linkable to CHANS and human–Earth system frameworks (Hubbard, 2016).

Table 1. Literature Clusters and Gaps Addressed by the Human Engine Framework

Literature Cluster	Main Focus	Gap Addressed by This Framework
CHANS & Human–Earth System	Bidirectional human–nature interactions, socio-ecological feedback, integrated modeling	Humans treated as aggregates (sectors, emission modules), not as internal processing engines of energy–information flows
Systems Thinking & Sustainability	Principles of interconnection, feedback, thresholds, and adaptive dynamics for complex problem-solving	Rarely visualizes humans as vertical nexuses connecting energy/information sources with material boundaries
Sky–Earth Metaphor	Humans as bridges between "sky" (energy, information domains) and "earth" (material substrate) in spiritual and ecological traditions	Not yet formalized as a systemic model linkable to CHANS and human–Earth frameworks

The synthesis of these three clusters reveals a theoretical gap: no model explicitly positions humans as *engines* processing vertical sky–earth flows and translating them into socio-ecological action. This gap provides the rationale for constructing the *Human Engine: Sky–Earth Flow* framework.

3.2 Conceptual Definitions and Scope

To ensure scientific rigor and avoid metaphysical ambiguity, each component is defined explicitly:

Sky Input Flow: Represents the flow of (a) physical energy and matter from the atmosphere and solar radiation (e.g., insolation, precipitation, climate signals), and (b) informational and normative signals (e.g., scientific knowledge, cultural values, policy information, spiritual inspiration) that humans receive from sources beyond immediate terrestrial contexts. This dual definition separates biophysical and informational dimensions while acknowledging both shape human responses.

Sky Output Flow: Represents emissions of (a) physical energy and matter back to the atmosphere (e.g., greenhouse gases, aerosols, heat), and (b) cultural and technological expressions (e.g., innovation, collective narratives, policies) that influence broader informational environments. Outputs from the human nexus feedback into sky-layer conditions, creating feedback loops.

Earth Grounded System: Represents the biophysical and socio-economic substrates that anchor human existence: ecosystems, geology, infrastructure, institutions, and opportunity structures. These provide both resources and constraints (carrying capacity, material limits, social norms, regulatory frameworks). The "Earth" metaphor emphasizes tangible, terrestrial dimensions distinct from atmospheric or informational domains.

Core Human Engine Nexus: Represents the biological, psychological, and social subsystems through which humans process sky–earth inputs into decisions and actions. This includes cognitive processing (perception, learning, reasoning), affective responses (emotions, values, motivation), and social mechanisms (communication, collective decision-making, institutional behavior). The "engine" metaphor emphasizes active transformation rather than passive reception.

Upward Vector: Represents behavioral and motivational tendencies oriented toward increased awareness, reflexivity, innovation, long-term planning, and regenerative practices. The "upward" direction signifies movement toward complexity, consciousness expansion, and alignment with sustainability principles. Magnitude represents strength of these tendencies; direction (angle) represents orientation toward specific values or goals.

Downward Vector: Represents grounding forces including immediate survival needs, material resource constraints, institutional inertia, short-term adaptive pressures, and entropic tendencies that resist change. The "downward" direction signifies pressures toward simplification, reactive behavior, and path-dependency. Magnitude and direction represent the intensity and focus of these pressures.

Analytical boundaries: "Sky" and "Earth" are analytical metaphors grounded in Earth system science and systems theory, not spiritual or metaphysical claims. The model excludes extra-terrestrial dimensions and focuses on human–environment interactions within Earth's atmosphere, biosphere, and social systems.

3.3 Formulation of the Human Engine Model

The primary result is a conceptual framework positioning *The Core Human Engine Nexus* as a processing center on the vertical axis between *Sky Input/Output Flow* and *Earth Grounded System* (Figure 1).

Sky Input Flow delivers energy and information to the human nexus. *Sky Output Flow* represents human emissions and expressions that feedback into upper-layer Earth system conditions. On the lower axis, *Earth Grounded System* provides the material substrate and institutional context that simultaneously enables and constrains human action.

Within the nexus, humans process diverse inputs through cognitive, affective, and social mechanisms, producing decisions and actions modeled as combinations of *Upward* and *Downward Vectors*. The resultant trajectory—magnitude and angle of the combined vector—determines whether system behavior trends toward regenerative sustainability or destructive overshoot.

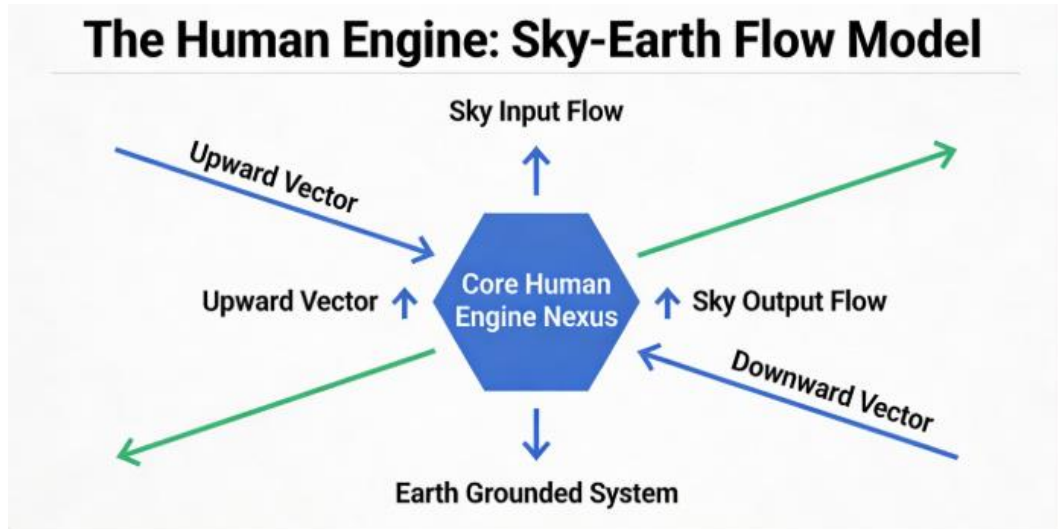


Figure 1. The Human Engine: Conceptual Framework of Sky–Earth Flows in Coupled Human–Natural Systems

How to read the model: Solid arrows represent flows of energy, matter, and information. Dashed arrows represent feedback pathways. The central human nexus receives inputs from above (Sky) and below (Earth), processes them internally, and produces outputs that feedback into both sky and earth layers. Vector arrows within the nexus represent the balance of transformational (*Upward*) and grounding (*Downward*) forces determining behavioral trajectory.

Table 2. Core Components of the Human Engine Framework and Theoretical Foundations

Component	Operational Definition	Supporting Theoretical Basis
Sky Input Flow	Physical energy/climate signals (insolation, precipitation) + informational/normative signals (knowledge, values, policy information) received by humans	Climate signals in human–Earth system models (Prinn, 2013); role of knowledge and values in sustainability systems (Wamsler & Restoy, 2020)
Sky Output Flow	Emissions of energy and matter (GHGs, aerosols) + cultural and technological expressions (innovation, narratives, policies) affecting atmospheric and informational environments	Emissions and technology modules in integrated climate–economy models (Prinn, 2013); human impacts on planetary boundaries (Rockström et al., 2009)

Earth Grounded System	Biophysical and socio-economic substrates: ecosystems, infrastructure, institutions, opportunity structures providing resources and constraints	Landscape, ecosystem services, and human well-being in CHANS literature (Liu et al., 2007); social-ecological resilience frameworks (Ostrom, 2009)
Core Human Engine Nexus	Biological, psychological, and social subsystems processing sky–earth inputs into decisions and actions (cognition, affect, social dynamics)	"Paradigm–perception–intention–action–impact" in sustainability systems thinking (Meadows, 2008); human agency in Earth system governance (Biermann et al., 2010)
Upward Vector	Tendencies toward awareness, reflexivity, innovation, long-term orientation, regenerative transformation (magnitude = strength; angle = value orientation)	Leverage points and paradigm shifts in systems thinking (Meadows, 1999); deep transformation in sustainability transitions (Abson et al., 2017)
Downward Vector	Grounding pressures: survival needs, material constraints, institutional inertia, short-term adaptation (magnitude = intensity; angle = focus)	Economic and social pressures reinforcing ecological overshoot in CHANS and planetary boundaries frameworks (Rockström et al., 2009; Liu et al., 2007)

3.4 Theoretical Propositions

From the model structure, three testable propositions are formulated:

Proposition 1: High quality and coherence of *Sky Input Flow* (rich information, clear values, supportive narratives) is positively associated with strengthening of *Upward Vector* (pro-environmental behavior, long-term orientation), provided that *Earth Grounded System* pressure (material scarcity, institutional barriers) remains within a manageable range.

Hypothesized mechanism: When individuals and communities receive high-quality environmental information and supportive cultural narratives, they develop stronger motivation for transformative action—but only if basic needs are met and institutional environments are not overly constraining.

Empirical strategy: Cross-sectional surveys measuring information quality, institutional support, and pro-environmental behavior across communities with varying resource access. Expected finding: positive correlation between Sky Input quality and Upward Vector strength in low- to moderate-pressure contexts; weaker correlation in high-pressure contexts.

Proposition 2: Excessive pressure from *Earth Grounded System* (severe resource scarcity, weak institutions, high vulnerability) strengthens the dominance of *Downward Vector*, encouraging short-term adaptive choices at the expense of long-term sustainability.

Hypothesized mechanism: When survival needs dominate, cognitive and motivational resources are directed toward immediate problem-solving, reducing capacity for reflexivity and long-term planning.

Empirical strategy: Comparative case studies of communities under varying stress levels (e.g., climate-vulnerable vs. climate-secure regions). Expected finding: higher Downward

Vector dominance in high-stress contexts, manifested as short-term coping over long-term adaptation.

Proposition 3: The dynamic balance between *Upward* and *Downward Vectors* is the primary determinant of system transition direction—either toward regenerative sustainability (Upward-dominant) or destructive overshoot (Downward-dominant).

Hypothesized mechanism: System trajectories emerge from the resultant vector of competing forces. When transformational forces (awareness, innovation) outweigh grounding pressures (scarcity, inertia), systems trend toward sustainability. When pressures dominate, systems trend toward degradation.

Empirical strategy: Longitudinal studies or system dynamics modeling tracking vector balance over time in relation to sustainability outcomes (e.g., resource management success, policy adoption, community resilience). Expected finding: Upward-dominant configurations predict positive sustainability outcomes; Downward-dominant configurations predict negative outcomes.

3.5 Comparative Positioning Against Established Frameworks

To clarify the incremental value of the *Human Engine* framework, Table 3 contrasts it with three established frameworks: CHANS, Ostrom's Social-Ecological System (SES) framework, and human–Earth system modeling architectures.

Table 3: Comparative Positioning: Human Engine vs. Established Frameworks

Framework	Primary Focus	Human Representation	Human Engine Contribution
CHANS (Liu et al., 2007)	Bidirectional feedbacks between social and ecological subsystems; emphasis on horizontal flows (land-use, resource extraction)	Humans as aggregates (sectors, populations); focus on material variables	Foregrounds internal human processing of vertical (sky–earth) flows; integrates values and consciousness
Ostrom (Ostrom, 2009)	Governance of common-pool resources; institutional analysis; nested hierarchies	Actors within institutional settings; emphasis on rules and norms	Adds vertical energy/information flows and psychological dimensions (motivation, reflexivity)
Human–Earth System Models (Prinn, 2013)	Integrated assessment of climate, economy, energy, land-use; policy scenario analysis	Humans as demand/emission modules; economic agents	Centers human agency as active processing nexus; emphasizes meaning-making and transformational capacity

Key differentiators:

1. *Vertical flow framing:* While CHANS and SES emphasize horizontal flows (between sectors, scales), the Human Engine highlights vertical flows connecting atmospheric/informational domains (sky) with terrestrial/material domains (earth).
2. *Internal human dynamics:* Existing frameworks typically treat humans as black boxes or aggregate actors. The Human Engine unpacks internal processing mechanisms (cognition, affect, social dynamics).

3. *Vector balance*: The Upward/Downward vector construct offers a novel diagnostic for assessing whether system configurations favor transformational or regressive trajectories.

3.6 Discussion

Theoretical Contributions to CHANS and Human–Earth System Literature

The *Human Engine* framework enriches CHANS literature by shifting focus from macro-system structures to the internal mechanisms through which humans process flows and produce feedback. While traditional CHANS models map relationships between landscapes, ecosystem services, and human well-being, this framework highlights how information and energy are processed within the human nexus before returning to the system as policies, technologies, or practices (Liu et al., 2007). This approach bridges biophysical CHANS with studies of individual values, consciousness, and motivation—dimensions often treated separately (Li et al., 2023).

In the context of human–Earth system interactions, the vertical sky–earth framing emphasizes that human responses to climate signals and policies are strongly mediated by the configuration of *Core Human Engine Nexus* (Prinn, 2013). This helps explain why similar policies produce divergent outcomes across communities with different risk perceptions, values, and reflexive capacities. Theoretically, the model proposes that paradigm shifts and input quality (knowledge, narratives, experiences) are as important as material incentive structures in determining sustainability transition pathways.

Implications for Systems Thinking and Sustainability Practice

From a systems thinking perspective, the model emphasizes humans as processing machines that not only redirect flow volume but also alter the quality of incoming signals (Meadows, 2008). The practical implication is that sustainability interventions increasing environmental "message quantity" without addressing *Earth Grounded System* context risk failure because they do not address *Core Human Engine Nexus* configuration and vector balance. Educational, leadership, or public policy programs aiming to strengthen *Upward Vector* must simultaneously reduce structural pressures producing high *Downward Vector*—for example, through social protection, basic needs provision, and environmental design supporting pro-environmental practices.

In policy and management practice, the framework (Tables 2 and 3) can serve as a diagnostic tool to identify intervention leverage points. Organizations or local governments can map actual conditions of each component—quality of climate information reaching citizens (Sky Input), economic pressures (Earth Grounded), and indicators of pro-environmental motivation (Upward Vector)—to develop more targeted strategies. This approach aligns with recent recommendations that conceptual modeling can enhance practitioners' systems thinking capacity by forcing identification of key components and relationships before quantitative analysis (Hörisch et al., 2025).

Operationalization Pathways

To transition the framework from heuristic to testable model, operational indicators are needed for each component (Table 4).

Table 4: Provisional Operational Indicators for Human Engine Components

Component	Potential Empirical Proxies	Measurement Approach
Sky Input Flow Quality	Climate information access; educational attainment; exposure to sustainability narratives; media diversity	Surveys (information literacy scales); content analysis (media framing); institutional data (education access)

Sky Flow	Output	Per-capita GHG emissions; technology adoption rates; policy innovation indices; cultural production (e.g., sustainability discourse frequency)	National/regional statistics; patent databases; text analysis of policy documents
Earth Grounded System Pressure		Resource scarcity indices (water, food, energy); infrastructure quality; institutional effectiveness; poverty rates	Environmental and social indicators (e.g., SDG dashboards); institutional quality indices (e.g., World Governance Indicators)
Upward Vector Strength		Pro-environmental behavior frequency; long-term planning orientation; reflexivity scores; participation in sustainability initiatives	Behavioral surveys (e.g., NEP scale, ecological footprint); time-preference experiments; organizational data (initiative participation)
Downward Vector Strength		Short-term coping behavior; resource competition intensity; institutional inertia indicators; risk aversion	Ethnographic observation; survival-strategy surveys; institutional change resistance indices

3.9 Limitations and Further Research Agenda

As a conceptual model, the *Human Engine* framework currently lacks proven mathematical formulation and validated operational indicators; its contribution is primarily heuristic. Model development relied on narrative literature review and remains subject to potential selection and interpretation bias, despite transparency measures. Key limitations include:

1. **Construct validity:** Components are defined but not yet operationalized with validated scales.
2. **Dynamic specification:** Feedback loops are depicted but not yet mathematically formalized.
3. **Empirical grounding:** Propositions are theoretically derived but not yet empirically tested.
4. **Boundary clarity:** While analytical boundaries are stated, practical application contexts require further specification.

Thus, this model is positioned as a starting point for interdisciplinary collaborations integrating CHANS, systems thinking, and mindfulness studies within a more holistic sustainability research framework.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This article introduces *The Human Engine: A Conceptual Framework of Sky–Earth Flows in Coupled Human–Natural Systems* as a theoretical model positioning humans as processing nexuses of energy and information flows between atmospheric/informational domains (sky) and terrestrial/material domains (earth). The framework synthesizes literature on CHANS, human–Earth system interactions, and systems thinking, enabling biophysical, cognitive, and value dimensions to be analyzed within a unified, feedback-driven system.

The main contribution lies in emphasizing the balance between *Upward* and *Downward Vectors* as determining system transition direction toward regenerative or destructive pathways, while offering a set of testable propositions for empirical validation. As a heuristic framework, the model bridges the gap between technical modeling and deeper

understanding of internal human dynamics within the Earth system. It provides conceptual scaffolding for interdisciplinary research, policy diagnostics, and sustainability education.

4.2 Recommendations

Further research should operationalize key components—*Sky Input Flow* quality, *Core Human Engine Nexus* configuration, and *Upward/Downward Vector* strength—as measurable indicators and model variables, enabling empirical testing of the three propositions through surveys, qualitative studies, and system dynamics modeling. Researchers should also systematically compare this framework with established CHANS and human–Earth system models to assess its additional explanatory power for variations in human responses to biophysical and policy pressures. Policymakers and sustainability practitioners can use the framework diagrams and tables as diagnostic tools to map factors strengthening or weakening *Sky Input Flow*, *Earth Grounded System*, and behavioral vectors in specific communities.

An integrated approach to sky, human, and earth dimensions is expected to produce more effective, context-sensitive, and highly leveraged sustainability transition strategies.

References

- Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., ... & Lang, D. J. (2017). Leverage points for sustainability transformation. *Ambio*, 46(1), 30–39. <https://doi.org/10.1007/s13280-016-0800-y>
- AIMES Project. (2022). Modeling Earth systems and human interactions. *Future Earth*. Retrieved from <https://aimesproject.org/mesh/>
- Biermann, F., Betsill, M. M., Gupta, J., Kanie, N., Lebel, L., Liverman, D., ... & Zondervan, R. (2010). Earth system governance: A research framework. *International Environmental Agreements: Politics, Law and Economics*, 10(4), 277–298. <https://doi.org/10.1007/s10784-010-9137-3>
- Hubbard, J. (2016). Reciprocity and the gift of teaching in Daoist xueguan. In *Teachers of inner chambers* (pp. 139-158). SUNY Press.
- Hörisch, J., Brieger, S. A., & Landzettel, L. (2025). Systems thinking: A review of sustainability management research. *Sustainability*, 17(1), 1–20. <https://doi.org/10.3390/su17010001>
- Jaakkola, E. (2020). Designing conceptual articles: four approaches. *AMS Review*, 10(1), 18-26. <https://doi.org/10.1007/s13162-020-00161-0>
- Li, Y., Sang, S., Mote, S., Rivas, J., Kalnay, E., & Liu, J. (2023). Challenges and opportunities for modeling coupled human and natural systems. *National Science Review*, 10(7), nwad054. <https://doi.org/10.1093/nsr/nwad054>
- Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., ... & Taylor, W. W. (2007). Complexity of coupled human and natural systems. *Science*, 317(5844), 1513–1516.
- Meadows, D. (1999). *Leverage points: Places to intervene in a system*. The Sustainability Institute, Hartland, VT.
- Meadows, D. H. (2008). *Thinking in systems: A primer*. Chelsea Green Publishing.
- Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419–422. <https://doi.org/10.1126/science.1172133>
- Prinn, R. G. (2013). Development and application of Earth system models. *Proceedings of the National Academy of Sciences*, 110(Supplement 1), 3673–3680. <https://doi.org/10.1073/pnas.1107470109>
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., ... & Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for

- humanity. *Ecology and Society*, 14(2), 32. <https://doi.org/10.5751/ES-03180-140232>
- Sukhera, J. (2022). Narrative reviews: Flexible, rigorous, and practical. *Journal of Graduate Medical Education*, 14(4), 414–417. <https://doi.org/10.4300/JGME-D-22-00480.1>
- Wamsler, C., & Restoy, F. (2020). Contemplative sustainable futures: The role of individual inner dimensions and transformation in sustainability research and education. In *Sustainability Science* (pp. 1-15). Springer. <https://doi.org/10.1007/s11625-020-00847-w>