Position Paper

Towards an eco-surplus culture

From market failures to vulnerabilities and logical flaws of 'artificial' environmental protection systems

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Abstract. *Following the Paris Agreement, global actors intensified climate action through ambitious pledges, financial alliances, and investments in* *green technologies. However, despite continued rises in atmospheric carbon concentrations and global temperatures, a series of structural regressions have emerged, exposing the deep vulnerabilities and inherent flaws of artificial environmental protection systems – systems predominantly shaped by mainstream economics' growth-oriented and technology-centric paradigms. This paper, grounded in Granular Interaction Thinking Theory (GITT), seeks to uncover the logical flaws embedded in such systems. It explains how they perpetuate the illusion that perpetual economic growth is compatible with environmental protection through prioritizing investment in advanced – yet often costly, low-impact, and highly uncertain – technological solutions. This bias also results in an overdependence on a limited range of technologies, heightening the risk of economic bubble formation and immiserizing growth. To address these systemic shortcomings, we advocate for the adoption of the semiconducting principle of monetary and environmental value exchange. This principle ensures that environmental values can be translated into monetary values, but not vice versa – thereby preventing monetary valuation from undermining ecological sustainability. Operationalizing this principle effectively requires the cultivation of Nature Quotient (NQ) across society and a broader socio-cultural shift toward an eco-surplus culture, in which environmental protection, restoration, and regeneration are not peripheral trade-offs, but foundational preconditions for long-term economic resilience, political stability, and social well-being. Such a profound transition will inevitably increase systemic entropy – manifesting as uncertainty and disruption across established socio-cultural and political patterns, norms, and structures. Accordingly, this paper also explores the major challenges that may hinder the emergence and diffusion of an eco-surplus culture, as well as strategies for addressing them.*

> "The villagers in the region have begun to favor eating small, crispy fried fish paired with beer. This type of fish is about to become the main driver of the surrounding villages' economic growth!"
>
> In "Bird Village Economics," *Wild Wise Weird* (2024)

1. Failures in climate change mitigation and environmental protection

Since the adoption of the Paris Agreement, governments, financial institutions, businesses, and other stakeholders have increasingly concentrated their efforts on climate change mitigation and adaptation. These efforts aim to limit global warming to well below 2°C above pre-industrial levels, with a more ambitious target of 1.5°C. By 2024, a total of 168 nationally determined contributions (NDCs) had been submitted during the UN Climate Change Conference (COP29) (UNFCCC Secretariat, 2024). The Net-Zero Banking Alliance (NZBA)—a coalition of leading global banks committed to aligning their portfolios with the 1.5°C target—expanded rapidly from 43 members in 2021 to 144 banks in 2024, collectively managing over USD 74 trillion in assets, representing approximately 41% of global banking assets (Global Climate Action, 2024; Programme, 2024). This mobilization—from regulatory reform to green financing—has been driven by a shared commitment to building a more resilient socio-economic system in the face of escalating climate risks.

However, 2024 marked a critical point. For the first time, the global average temperature for a full calendar year exceeded 1.5°C above pre-industrial levels. Although the Paris Agreement defines this threshold as a 20-year average, many climate scientists now argue with high certainty that 2024 signals the beginning of a sustained period of warming at or above this level (Bevacqua et al., 2025; Cannon, 2025). Given this alarming development, one might expect a surge in climate action and investment. Yet, in reality, failures across the world's socio-economic systems have emerged.

The global voluntary carbon market continuously experienced dramatic contractions. According to Ecosystem Marketplace (Greenfield, 2024), the market value of carbon offsets plummeted by 61%, from USD 1.9 billion in 2022 to just USD 723 million in 2023. This decline followed a series of scientific and investigative reports revealing that many carbon offset projects fail to deliver real emission reductions or biodiversity benefits. A study by Probst et al. (2024), covering nearly one billion tons of CO_2e credits—roughly one-fifth of all issued credits—found that fewer than 16% of the investigated credits reflected actual emissions reductions. By the end of 2024, the average price of voluntary carbon credits had continued to decline sharply, reaching just $4.80 per ton, a 20% drop from the previous year and the lowest level in several years. This figure is less than one-fifteenth of the $75 per ton benchmark projected by the IMF as necessary by 2030 to stay on track for the 2°C climate target (Black et al., 2022;

Jennifer, 2025). While oversupply remains a key driver of the decline, the downturn was further exacerbated by a series of executive orders issued by President Trump on energy and environmental policy—including the U.S. withdrawal from the Paris Agreement—despite rising atmospheric carbon emissions. A recent consequence of this policy direction was observed on April 9, 2025, when prices for California Carbon Allowances and Regional Greenhouse Gas Initiative Allowances plunged by nearly 25% and 13%, respectively, following an executive order aimed at reviving "clean coal" initiatives (Gacad & Pinto, 2025).

Warning signs of oversaturation in the battery industry have begun to surface. Northvolt—a key player in Europe's effort to establish a domestic battery supply chain, backed heavily by European automakers and positioned as a potential rival to dominant Asian manufacturers—filed for bankruptcy in Sweden after months of unsuccessful fundraising. At the same time, several Western mining companies have started scaling back their operations in battery metal markets due to falling commodity prices. For example, in early 2025, Anglo-American divested its Brazilian nickel operations, citing oversupply-driven price pressures (Home, 2025a). Since peaking in March 2022, the price of nickel has plunged by more than 68%, from USD 48,226 to USD 15,393 per ton (Trading Economics, 2025c). Similar downward trends have occurred in other critical metal markets: cobalt prices have dropped by approximately 59% (from USD 82,000 to USD 33,700 per ton), while lithium has seen a dramatic decline of nearly 89% (from USD 597,500 in November 2022 to USD 67,950 per ton) (Trading Economics, 2025a, 2025b). Not only are businesses collapsing, but large swathes of tropical forest—some of the most carbon-rich and ecologically vital ecosystems on the planet—have also been cleared for metal extraction, often under the guise of sustainability pledges (Ruehl & Dempsey, 2023; Vuong, Nguyen, & La, 2025; Wahyono et al., 2024).

Meanwhile, the Net-Zero Banking Alliance (NZBA), established less than five years ago, is facing a significant decline in both membership and total asset coverage. Following the election of Donald Trump as the 47th President of the United States, several major U.S. banks—including Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, and Wells Fargo—withdrew from the Alliance. They were soon followed by Canada's five largest banks—TD Bank, Bank of Montreal, National Bank of Canada, Canadian Imperial Bank of Commerce, and Scotiabank (Frost, 2025). In addition, five out of six Japanese member banks exited the Alliance, with Mizuho Financial Group being the most recent departure (Costa, 2025). Together, the withdrawing institutions accounted for approximately 39% of the NZBA's total asset coverage (Iyer & Tan, 2025). Under mounting pressure from declining membership and reduced financial influence, the Alliance officially downgraded its climate ambition in April 2025, replacing its 1.5°C target with a 2°C target, less than six months after the results of the 2024 U.S. presidential election (Furness, 2025).

Notably, just weeks after Spain's grid operator, Red Eléctrica, announced that renewable energy sources had fully met national electricity demand, the country experienced a severe blackout (Molina, 2025). On April 28, 2025, the most extensive power outage in Europe in recent history struck Portugal and Spain, with minor disruptions extending to adjacent regions in Andorra and southwestern France (Brezar & Skopeliti, 2025). The blackout brought critical services—such as grocery stores, pharmacies, traffic lights, and public transportation—to a standstill. Casualties have also been reported as a result of the blackout (RTVE.es, 2025). While the precise causes have yet to be officially disclosed and may take months to investigate fully, one of the preliminary explanations points to vulnerabilities in renewable energy systems. Although this cause remains contested, the incident alone is sufficient to undermine public trust in the reliability of renewable energy.

These seemingly isolated events reflect a broader systemic trend concerning the very solutions promoted to protect the environment and combat climate change. First, systems heralded as breakthroughs for climate resilience and the sustainability of socio-economic structures appear to be highly fragile, vulnerable to rapid, large-scale collapse. A single political, economic, or technical shock may be sufficient to destabilize systems that are otherwise presented as scientifically robust, theoretically sound, widely supported, and sustainable. Yet all definitions of "resilience" emphasize a system's capacity to withstand and quickly recover from shocks and disruptions. How, then, can a "sustainable" socio-economic structure built upon such vulnerable artificial systems be deemed truly resilient?

Moreover, questions arise regarding the principle of equitable benefit-sharing—often praised in declarations about "just transitions" (Dall-Orsoletta et al., 2022; Goddard & Farrelly, 2018; Hoicka et al., 2021; Szabó & Newell, 2024). When markets collapse due to the exit of major players, why are there no immediate replacements to restore balance? This defies basic market principles, as a truly functional and equitable system would naturally facilitate the entry of new participants to fill the gap. These patterns indicate a fundamental flaw in the principles underpinning the current system design. Specifically, implementation processes appear to be driven more by ideological conviction, vested interests, and, in some cases, weaponized for economic, political, or geopolitical contestation.

In a recent paper published in *Visions for Sustainability*, we examined the progress and challenges associated with the predominant strategies currently employed to mitigate climate change and prevent environmental degradation (La et al., 2025). Drawing on empirical data and evidence, we demonstrated that despite notable advances in renewable energy, international agreements, technological innovation, and carbon market mechanisms, global greenhouse gas emissions remain at historically high levels. Climate change continues to accelerate, ecosystems are increasingly degraded or destroyed, and biodiversity loss is worsening at an alarming rate. Predominant solutions, which are largely rooted in a growth-oriented paradigm and reliant on technological interventions, have proven insufficient. In many cases, these approaches perpetuate existing exploitative paradigms rather than transforming them.

This paper, conceived as a continuation of the previous work, aims to identify the fundamental logical flaws inherent in artificial environmental protection systems—specifically, those socio-economic systems grounded in mainstream economic paradigms that are premised on the illusion of perpetual growth. We apply the Granular Interaction Thinking Theory (GITT) to offer an analytical explanation of how mainstream economics has contributed to reinforcing the eco-deficit culture within human socio-economic structures, as well as four major logical flaws of such a paradigm. Based on the mechanisms and principles outlined in GITT, we propose adopting the semiconducting principle of environmental and monetary value exchange as a means to address the systemic flaws embedded in current socio-economic frameworks.

To ensure the effective implementation of the semiconducting principle, enhancing the Nature Quotient (NQ) and cultivating an eco-surplus culture are indispensable prerequisites. Building an eco-surplus culture will inevitably face numerous challenges, as it calls into question entrenched socio-cultural, political, and economic paradigms. Consequently, this paper also discusses several challenges that may hinder the formation of an eco-surplus culture and the adoption of the semiconducting principle. We offer preliminary reflections on how these challenges might be addressed.

2. The dominance of growth-oriented and technology-centric worldviews

2.1 A Granular Interaction Thinking Theory perspective

Granular Interaction Thinking Theory (GITT) offers a valuable lens to identify and clarify foundational design flaws of the current artificial environmental protection systems (Vuong, La, et al., 2025a; Vuong & Nguyen, 2024a, 2024b, 2024c). Grounded in the granular worldview of quantum mechanics (Hertog, 2023; Rovelli, 2018), Shannon's information theory (Shannon, 1948), and mindsponge theory (Vuong, 2023), GITT conceptualizes information as a measure of the number of possible alternatives for something. In quantum reality, each quantum unit carries information, implying that systems composed of multiple quanta inherently contain diverse possibilities (Rovelli, 2018). This aligns with John Wheeler's "it from bit" notion that physical reality originates from information (Wheeler, 2002).

Within the GITT paradigm, two primary spectrums serve as foundational elements: the mind and the environment. The mind functions as an information collection-cum-processor, while the environment serves as a broader information-processing system, like the climate and Earth system. A core feature of GITT, derived from quantum mechanics, is the principle of relationality. This principle posits that all events in the world are fundamentally interactions, and that the variable properties of any object exist only in relation to other objects. This perspective underscores the interconnectedness of all systems, particularly the dynamic interrelationship between human beings and their environments, echoing what Capra and Luisi (2014) describe as "the fundamental interdependence of all phenomena and the fact that, as individuals and societies, we are all embedded in (and ultimately dependent on) the cyclical processes of nature." Within this relational structure, the mind is constantly engaged in a reciprocal exchange with its external environment, continuously modifying and reorganizing itself in order to persist and evolve. Only those systems that can effectively manage this interaction are capable of sustaining and advancing their existence. In other words, survival and adaptation in a dynamic environment hinge on the efficient management of information: its acquisition, storage, transmission, and processing. This core principle aligns with Darwinian evolutionary theory (Darwin, 2003; Darwin & Wallace, 1858).

In this theoretical context, human society as a whole can be conceptualized as a collective mind—an information collection-cum-processor. This collective mind operates and optimizes its functions to fulfill its objective: sustaining human existence and enhancing the quality of life and social welfare (Vuong, 2023; Vuong & Napier, 2015; Vuong et al., 2022). This human system is not isolated but is nested within the broader Earth system—a complex network of interacting, information-processing systems. As such, it is deeply interlinked with its informational environment through processes of input (information, energy, and matter absorption) and output (impacts created through human actions). The majority of these input-output exchanges are channeled through economic systems, involving the production, distribution, and consumption of goods and services, along with waste disposal.

Just as quanta, atoms, molecules, and energy form the fundamental building blocks of biological cells—the foundation of both natural systems and human life (Ernberg et al., 2022; Kurian, 2025; Schrödinger, 1944)—human society also exhibits the property of granularity. In this view, information (including energy) is inherently finite. As the number of discrete informational units—or "grains of information"—within a system increases, the informational entropy (i.e., uncertainty or missing information) within the system also rises (Vuong & Nguyen, 2024c). This entropy can be formally quantified using the entropy formula of Shannon (1948):

$$H(X) = -\sum_{i=1}^{n} P(x_i) \log_2 P(x_i)$$

$H(X)$ is the informational entropy of a random variable X with possible outcomes $\{x_1, x_2, \dots, x_n\}$ and corresponding probabilities $\{P(x_1), P(x_2), \dots, P(x_n)\}$. $P(x_i)$ is the probability of the outcome x_i. Each probability $P(x_i)$ represents how likely each outcome x_i is to occur. In this context, the variable X can be interpreted as humanity's collective mind in the current state, with i number of information units. Each information unit has its $P(x_i)$ probability to be stored and processed within the mind. According to this formula, when the number of information units increases without clear differentiation and prioritization of their importance, informational entropy will rise rapidly, reaching a maximum when all information is equally important, precisely when $P(x_i) = \frac{1}{n}$. Under such conditions, humanity faces the highest risk of informational overload and information loss. Without an effective mechanism to prioritize information, the system suffers from decision paralysis, misallocation of resources, and stagnation in policy and innovation.

To optimize the limited cognitive and energetic resources essential for continued survival and development, humanity must systematically evaluate, differentiate, compare, integrate, and assign varying degrees of importance to different information units. This prioritization process - essentially a process of value formation - enables the system to efficiently store and process the most relevant information for adaptive functioning. These values are not formed in isolation but emerge through dynamic interactions among various constituents of humanity, including nations, institutions, social groups, and individuals. The value formation is probabilistically determined but not unequivocally, reflecting the third major feature of GITT (besides granularity and relationality): indeterminacy.

Through these interactions, the collective mind assigns higher probabilities of retention and processing to information units deemed beneficial to survival, progress, and long-term continuity. Conversely, information that is evaluated to be irrelevant, contradictory, or costly to process is assigned lower probabilities or filtered out altogether. This selective process helps reduce informational entropy and conserve system energy. Once formed, values serve as benchmarks or filters: information (e.g., worldviews, norms, beliefs, and theories) that aligns with prevailing values is more likely to be retained, whereas conflicting or misaligned information tends to be excluded or marginalized.

From mainstream economics to eco-deficit Culture

Humanity's prevailing socio-economic systems - including those ostensibly designed for environmental protection - remain largely governed by values centered on economic growth and technological advancement. These values have gained dominance over recent decades, as they are widely regarded as essential to human survival, societal progress, and the continuity of civilization.

Throughout history, innovation has been a foundational element in sustaining and advancing human life. Breakthroughs such as the discovery of fire, electricity, penicillin, and the invention of the compass, steel, and steam engines have propelled civilizations forward, helping societies to overcome adversity and build resilience. One of the major benefits that innovations bring to humankind is power (Green, 1998): "the ability to create or prevent change." This transformative potential became particularly evident during the Industrial Revolution of the 18th and 19th centuries. The shift from manual labor to mechanized production dramatically boosted productivity, resulting in unprecedented population growth, rapid economic expansion, vast wealth accumulation, and sweeping social transformations (Ding, 2021). These developments also laid the groundwork for what economic historians call the

Great Divergence—whereby Western Europe and the United States (U.S.) escaped historical constraints on growth and emerged as global economic powers between the 18th and mid-20th centuries (Clark & Feenstra, 2003; Maddison, 2007). While Western nations were the initial beneficiaries, other countries also benefited through knowledge diffusion and technological spillovers.

The Industrial Revolution also triggered significant shifts in social organization and scientific inquiry. Economic surpluses and the growing demand for scientific knowledge catalyzed the emergence of modern science during the 19th century. As a result, humanity's understanding of nature expanded substantially, enhancing its capacity to modify or control natural processes. This deepening scientific knowledge has continued to accumulate, expanding human capabilities to alter ecological systems.

Concurrently, these developments have transformed the dominant human-nature relationship. In early agricultural societies, humans were characterized by obedience to nature as they lacked an adequate level of science and technology to understand a large number of natural phenomena, often relied on the food available in nature to prolong their existence, and had almost no resistance to natural disasters (Ding, 2021). Over time, however, advancements in science and technology gradually supplanted this sense of humility with anthropocentric confidence - the belief that innovation and technological progress can resolve environmental crises, including climate change and ecological degradation.

The philosophical and economic underpinnings of the Industrial Revolution were heavily influenced by Adam Smith's *The Wealth of Nations* (1776). Since then, classical and, subsequently, neoclassical economic thought have profoundly shaped global academic curricula and socio-economic worldviews. Neoclassical economics, bolstered by mathematical formalism, dominates university education and scholarly literature (Neck, 2022), reinforcing key assumptions such as rational self-interest, the feasibility of perpetual growth, and the precision of quantitative modeling. These assumptions shape the perspectives of students, researchers, and future decision-makers. Due to its academic prestige and institutional influence, neoclassical economics continues to serve as the primary framework for public policy and strategic planning (Dequech, 2012).

At the heart of this paradigm lies the notion of the rational economic man ("*Homo Oeconomicus*"), who seeks to maximize utility and responds predictably to monetary incentives (Mun, 1664; Persky, 1995; Smith, 1776). As Levitt and List (2008) explain, this notion presumes individuals are "unswervingly rational, completely selfish, and can effortlessly solve even the most difficult optimization problems." Mainstream economists, therefore, argue that promoting capital accumulation among individuals ultimately enhances societal welfare, including through the mitigation of socio-environmental problems generated by growth-centric economic activity.

In this view, economic growth is institutionalized as a core value embedded within humanity's information-processing system. It informs the behaviors of policymakers, entrepreneurs, managers, and the public, structuring socio-economic systems toward the goal of perpetual expansion. A prominent example is the Environmental Kuznets Curve (EKC) hypothesis, which suggests that while economic growth initially exacerbates environmental degradation, it eventually leads to environmental restoration and improvements once a certain income threshold is reached (Kijima et al., 2010; Özokcu & Özdemir, 2017).

Mainstream economic models' estimations and projections need to be based on market equilibrium. According to this view, the "invisible hand" of competition facilitates optimal allocation of resources through the balancing of aggregated supply and demand. When equilibrium is achieved, societal output and utility are presumed to be maximized, including the resolution of environmental challenges. These foundational assumptions are embedded in economic pedagogy, often referred to as the "1-2-3 Toolbox" of demand, supply, and equilibrium in introductory economics texts (Bichler & Nitzan, 2021). However, for these models to function, economists must assume that all other factors influencing demand and supply remain unchanged - a simplification that rarely holds true in complex socio-environmental systems.

In addressing climate change and environmental degradation, environmental economists have largely adopted these same principles. Environmental costs are treated as externalities that distort market efficiency. Consequently, economists advocate for government intervention to internalize these costs through pricing mechanisms (e.g., carbon market), thereby realigning market behavior to avoid inefficiencies (Wiesmeth, 2012). The expectation is that, once all externalities are adequately accounted for, market forces will guide society toward the most efficient solutions (Anderson & Leal, 2015; McCarthy, 2004).

The growth-centric paradigm is also deeply rooted in anthropocentrism - the belief that humans are the central entity on the planet and that nature exists primarily as a resource for human use. As Oelschlaeger (1991) observes, nature is often reduced to "nothing more than matter-in-motion," devoid of intrinsic value. Within this framework, plants, animals, and ecosystems are valued primarily for their utility to human endeavors (Boslaugh, 2016). From this perspective, prioritizing the well-being of the nonhuman world may even be seen as threatening to human interests (Doudaki & Carpentier, 2023; Harding, 2019). In extreme cases, this worldview has fueled climate change denial, despite overwhelming scientific consensus on the anthropogenic origins of global warming (Earth Science Communications Team, 2023; Lynas et al., 2021; Powell, 2017).

The ascendancy of neoclassical economics in academia and policy has further entrenched anthropocentric narratives that equate sustainability with continued economic and technological progress (Hajer, 1995; Pal & Jenkins, 2014). Corporations frequently leverage these narratives to justify the exploitation of environmental resources under the guise of sustainable development. Nature is commodified, assigned economic value, and treated as a source of commercial products, while environmental degradation is expected to be mitigated through efficiency gains and technological innovation (Pal & Jenkins, 2014).

This ideological alignment between economic growth and environmental stewardship has shaped contemporary climate strategies. For example, the IPCC (2023) emphasizes systemic transitions primarily focused on phasing out fossil fuels and scaling up renewable energy. Although nature-based solutions are increasingly recognized, they remain marginal in policy priorities. According to the United Nations Environment Programme (UNEP, 2023), in 2022, approximately $7 trillion in government subsidies and private investments were directed toward sectors that harm nature, around 35 times the $200 billion allocated to nature-based solutions.

These dominant growth- and technology-centric values have fostered the "eco-deficit culture" - a societal orientation that treats environmental value as a tradable commodity in pursuit of economic, political, or strategic interests (Vuong, 2021a, 2021b). Within this paradigm, environmental initiatives are undertaken primarily when they align with economic gain. Consequently, when political or market conditions shift, such initiatives are often deprioritized or abandoned in favor of alternatives that offer greater short-term returns. This market-driven approach harbors profound structural vulnerabilities that undermine long-term environmental protection. These shortcomings will be critically examined in the subsequent subsections.

3. The logical flaws of artificial environmental protection systems

3.1 The absurdity of nature valuation

Economic growth has long been the central objective of modern societies, shaping epistemologies, value systems, and policy frameworks across diverse disciplines. Within mainstream economic paradigms, nature is predominantly construed through an instrumental lens, as "natural capital" or a reservoir of ecosystem goods and services that can be utilized for human use. This growth-oriented perspective extends the logic of the market into environmental governance, advancing the notion that all dimensions of nature's value can be monetized and made comparable through a singular monetary indicator (Martin-Ortega et al., 2019). Consequently, environmental decisions are frequently guided by cost-benefit analysis and related evaluative tools, which reduce nature's multifaceted contributions to quantifiable price signals.

The ecosystem services - referring to the processes through which ecosystems sustain and enhance human life - was originally introduced as a metaphor to underscore society's dependence on ecological systems (Costanza & Daly, 1992; Daily, 1997; De Groot et al., 2002; Millennium Ecosystem Assessment, 2003; Norgaard, 2010; The Economics of Ecosystems and Biodiversity, 2010). By "pricing the priceless," environmental externalities can be internalized into market mechanisms, thereby aligning ecological preservation with economic self-interest (Banzhaf, 2023). Embedded within this logic is the assumption that once externalities are priced and incorporated into market mechanisms, the allocation of labor and capital will eventually respond to optimize environmental outcomes (Anderson & Leal, 2015; McCarthy, 2004). This approach also presupposes that individuals act as rational utility-maximizing agents and that environmental trade-offs can be objectively decided by comparing costs and benefits to aggregate welfare. Consequently, mainstream environmental economics typically rests on the assumption that the values and benefits provided by nature can be represented as measurable "changes in human well-being' arising from the provision of [an environmental] good or service" (Bateman et al., 2002). Within this framework, individuals are presumed to be rational agents who seek to maximize their well-being based on substitutable preferences (Pearce & Turner, 1989). This approach has become one of the most prominent strategies that are widely used for environmental policymaking at the international and national levels (Martin-Ortega et al., 2019).

Such market-based mechanisms are believed to support evidence-based environmental management among policymakers, businesses, and agencies by facilitating "optimal" decisions, defined as those that deliver a net positive economic return once all costs and benefits are accounted for. In this framework, "utility" is employed as a proxy for individual welfare, typically expressed in monetary terms (Hanley et al., 2009). Since utility lacks a cardinal unit of measurement, monetary valuation is used as a substitute. Ideally, a cost-benefit analysis aggregates gains and losses in utility across individuals to determine whether a proposed action yields a net benefit.

To operationalize these calculations, economists distinguish between two broad categories of ecosystem values (Hanley et al., 2009): Market and non-market environmental values. Market environmental values refer to the existing market prices of those that are already traded (e.g., timber, oil, carbon credits). For services not traded in markets (e.g., clean air, climate regulation, aesthetic beauty), various indirect methods are used, including contingent valuation (measured through questionnaire), travel cost model (measured through time and travel expenses proxying for recreational values), hedonic price method (measured through performing regression analysis to estimate the coefficients of the hedonic price function), production function approach (through valuing environment as input and estimating how much the change in environmental and resource systems affects production and cost), etc.

These value measurements attempt to reveal the latent preferences of individuals concerning ecological values. However, they are grounded in highly subjective constructs—shaped by beliefs, cultural norms, informational access, and cognitive biases—which raises fundamental concerns about their validity and reliability in measuring and valuing objective reality (i.e., ecosystems, climate, biodiversity). Even market-based values (like the price of timber or fish) are incomplete indicators of total value, because markets only reflect the values of those who participate and have purchasing power. This gives rise to distributional biases which effectively weigh people by income, potentially undervaluing impacts on poorer communities or future generations who are not "in the market".

In fact, behavioral environmental economics has provided evidence for the profound limitations of the rational-actor model. The theory of bounded rationality reveals that decision-makers operate under conditions of limited cognitive capacity, time constraints, and imperfect information (Botzen et al., 2025; Simon, 1990). In domains characterized by uncertainty and complexity - such as climate change or biodiversity loss - individuals often rely on heuristics that result in suboptimal choices. For instance, individuals may underappreciate low-probability, high-impact risks, undermining efforts at climate adaptation and disaster preparedness (Botzen et al., 2025). Kahneman (2011)'s dual-process theory further suggests that many environmental decisions are governed by "System 1" thinking - fast, intuitive, and emotionally driven - rather than by deliberative and analytical "System 2" reasoning (Kunreuther, 2020). As such, individuals may prioritize immediate, tangible benefits (e.g., convenience, cost savings) over long-term, abstract outcomes (e.g., emissions reduction), even when the latter would yield greater aggregate benefits.

Beyond cognitive limitations, human motivation is not exclusively economic. Social norms, ethical commitments, and cultural attachments frequently guide environmental behavior. However, the monetization of ecosystem services risks displacing these motivations. In development contexts, for example, the destruction of ancestral lands may be considered an "intangible" disamenity difficult to monetize, while revenue from resource extraction is readily quantifiable, creating a bias in evaluative frameworks. Relational values - those derived from identity, sense of place, or communal practices - are typically excluded from economic valuation or approximated through inadequate proxies (Nilgen et al., 2024; Stålhammar & Thorén, 2019). These values are often non-substitutable and embedded in cultural narratives, spiritual worldviews, and long-standing human-nature relationships. Scholars such as Nilgen et al. (2024) argue that trying to monetize such relational values risks "reducing complex socio-cultural, spiritual, and emotional relationships with nature to a single monetary figure", a process that can distort or erase what matters most to people in those relationships. In their study of climate adaptation planning in Bangladesh, participants allocated significantly more resources to adaptation when informed about potential losses to cultural heritage and social cohesion.

Perhaps the most significant shortcoming of cost-benefit-based valuation is its inability to account for systemic uncertainty and nonlinear ecological dynamics adequately. Ecosystems are complex and non-linear systems prone to tipping points - critical thresholds beyond which change becomes abrupt, irreversible, and self-reinforcing (e.g., polar ice sheet collapse, Amazon rainforest dieback). Conventional economic models typically employ smooth damage functions, assuming that environmental degradation unfolds incrementally and predictably. These assumptions break down in the face of abrupt climate transitions. When tipping points are crossed, the resulting damage may be so severe and qualitatively transformative that it defies usual risk calculations. The collapse of a biome or a fundamental shift in Earth's climate regime cannot be meaningfully quantified in dollar terms. Nevertheless, "save for a few fragmented studies, climate economics has either ignored them, or represented them in highly stylised ways," leaving most estimates of climate damages likely understating the true risks (Ward, 2021).

Recent assessments by institutions such as the UK's Institute and Faculty of Actuaries and Carbon Tracker reveal that conventional models systematically underestimate the impacts of climate change. These models' estimations often exclude essential variables such as ecological tipping points and precipitation variability, while employing unrealistic assumptions like the unaffected status of indoor workspaces (Keen, 2023; Trust et al., 2023). Due to these absurd valuations, they produce projections that are increasingly disconnected from climate realities (Keen, 2023):

- Some economists have suggested that a 6°C rise in global temperatures would reduce future global GDP by less than 10% compared to the projected GDP if there were no climate change at all.
- Pension funds have claimed that global warming of 2–4.3°C would have minimal effects on investment portfolios.

The monetization of nature, in these instances, functions less as a policy tool but more as a communicative weapon, trivializing the existential threats posed by climate change, biodiversity loss, and environmental collapse to the central banks' manipulable money supply.

Some might argue that it can serve as "a pragmatic short-term strategy to communicate the value of biodiversity in a language that reflects dominant political and economic views" (Gómez-Baggethun & Ruiz-Pérez, 2011). However, misestimations can lead to significant long-term consequences, as many environmental damages are irreversible. If the absurdity of ecosystem services valuation goes unrecognized, economists may inadvertently support environmental destruction by validating mass trading mechanisms. This, in turn, can transform these mechanisms into national and international policies that are widely propagated, like the carbon credit market.

3.2 The inability to value extinction

Efforts to internalize nature into market mechanisms often generate an illusion of environmental protection. In reality, these mechanisms may inadvertently accelerate ecological degradation. The foundational flaw lies in the epistemological and practical limitations of economic valuation. As previously discussed, such valuation techniques are unable to fully capture the intrinsic, relational, and non-substitutable values of an extinct species.

Consider, for example, the seemingly trivial case of a bird's nest discovered on the edge of a banana leaf. At first glance, it might not even be recognized as a nest, much less valued as a functional ecological unit. The nest - constructed by a flowerpecker using thread-like fibers to stitch the leaf edges and filled with trash - was only noticed because of the bird's song. The author (V.Q.-H.) would have passed it unnoticedly were it not for this surprise auditory cue. It also took him over a week to recognize that what seemed to be trash was, in fact, the carefully crafted home of a living being, actively contributing to its surrounding ecosystem.

Figure 1. A flowerpecker's nest. Taken on August 5, 2014, in the outskirts of Son Tay, Hanoi Capital Region (Source: Q.-H.V.)

Humans have long regarded knowledge as inherently valuable. Yet one must ask: what is the monetary worth of such a specific piece of understanding? Is there any market capable of pricing such knowledge? And if so, by what mechanism would it operate? Beyond ecological functions, the sights, sounds, and lived encounters with birds carry profound aesthetic, cultural, and educational value. These experiences often serve as inspiration for literature, poetry, music, visual arts, and environmental learning (Coscieme, 2015; Gould & Lincoln, 2017; Jokela & Huhmarniemi, 2020; Reason & Gillespie, 2023; Shibasaki et al., 2024; Vuong & Nguyen, 2023a, 2023b). But how can such intangible and relational values be translated into economic terms?

In his seminal work, *What is Life?*, Schrödinger (1944) posits that the defining challenge for living organisms is the maintenance of order in a universe that naturally tends toward disorder. From this perspective, the emergence and persistence of highly ordered life forms - each a product of intricate biological and evolutionary processes - represent an extraordinary feat of natural organization. What, then, is the value of such a being? How can we possibly quantify the immense effort embedded in sustaining life against the universal current of disorder?

Unlike financial markets - where central banks can generate money through policy decisions - nature operates under fundamentally different principles. One of the most definitive among them is extinction. When a species vanishes, humanity even loses the chance to value it, not to mention recognize its associated values within a larger ecosystem network. In such cases, should we resort to valuation methods based on replacement costs - estimating the worth of entity A by referencing a functionally or economically equivalent entity A*?

If we follow this logic, it could lead to absurd conclusions (Nguyen & Vuong, 2025). For example, an extinct dinosaur might be valued at the equivalent of 3,000 chickens simply because of genetic proximity. Such reasoning exposes the epistemological shortcomings of applying economic proxies to the valuation of irreplaceable life forms. It trivializes the uniqueness of evolutionary history and overlooks the multidimensional roles that extinct species once played in ecological systems.

When extinction defies valuation, market-based solutions lose their functional legitimacy. This exposes a critical disjunction between climate change and biodiversity loss - two intrinsically linked and mutually reinforcing dimensions of ecological issues. Rising global temperatures are already inflicting widespread damage on vital ecosystems such as coral reefs, mangroves, seagrasses, and wetlands, while simultaneously altering oceanic chemistry through acidification, hypoxia, and expanding dead zones. These environmental shifts intensify biodiversity loss driven by anthropogenic pressures. Projections indicate that a 2°C increase in global temperature would result in the contraction of geographic ranges for an estimated 18% of insect species, 16% of plants, and 8% of vertebrates, making localized extinctions almost inevitable. Beyond this threshold, the probability of widespread, irreversible species loss will grow substantially by the end of the 21st century (McElwee, 2021). Simultaneously, as biodiversity declines, ecosystems become increasingly fragile and less capable of buffering against climatic variability, whether wet or dry, extreme or moderate, short-lived or prolonged (Isbell et al., 2015).

Given the systemic interdependence between climate regulation and biodiversity, one would expect that a functioning carbon market, designed to mitigate greenhouse gas emissions, might also yield co-benefits for biodiversity. Yet, this is not the case. Market mechanisms cannot resurrect extinct species, nor can they prevent extinctions that result from delayed or insufficient action. Some economists have proposed the establishment of a parallel biodiversity credit market to address this gap (Waterford et al., 2023). But even such proposals face a fundamental challenge: How can we determine the appropriate level of investment to safeguard billions of marine organisms - many of which remain undiscovered - from perishing under intensifying thermal stress and increasingly frequent "heat dome's scorching temperatures"? (McElwee, 2021).

The rapid decline of emperor penguins offers a sobering illustration of this conundrum. By the end of 2022, four major colonies in the Bellingshausen Sea experienced catastrophic breeding failures due to the accelerated melting of Antarctic sea ice. This collapse, which interrupted feeding cycles and nesting stability, resulted in the death of an estimated 7,000 chicks. While scientists had long warned that warming seas posed existential risks to ice-dependent species like the emperor penguin, the scale and timing of the collapse surpassed prior projections (Fretwell et al., 2023). Since 2018, nearly 30% of Antarctica's 62 known penguin colonies have been affected by partial or complete ice loss. Without urgent and large-scale intervention, projections suggest that 90% of colonies could face population declines so severe as to be considered functionally extinct by 2100 (Readfearn, 2023).

Notably, penguins have historically been regarded as relatively safe from the conventional drivers of species decline - namely, hunting, trafficking, and land-based habitat destruction. Now, however, they are on the brink of collapse due solely to climate-induced habitat degradation. Lacking any form of commodified status, the economic value of a penguin has never been formally acknowledged. Yet paradoxically, the global economic system - through instruments such as emissions trading - implicitly places a monetary cost on their death. For example, each ton of carbon traded on the market contributes incrementally to climate change, and by extension, to the loss of species like the emperor penguin.

As populations dwindle, the hypothetical "market value" of the remaining individuals could rise, mirroring the logic of scarcity-driven pricing. This leads to an economic paradox. Although no technical framework exists to calculate the value of a penguin, it is plausible to say that their existential worth is escalating as they approach extinction, perhaps to a degree that challenges anthropocentric value hierarchies. In the depths of the climate crisis, the symbolic and ecological value of such a species may ultimately exceed that of individual human lives.

This absurdity highlights the limitations of attempting to frame nature in purely economic terms. The very notion that market logic could apply to penguins—or any endangered species - reveals an underlying contradiction: Antarctica, once a self-regulating biome due to its stable ice coverage, now requires human-led conservation efforts to prevent further collapse. But what can conservation preserve when the foundational element of the ecosystem - ice - is already disappearing?

3.3 Prioritization of expensive and low-effective alternatives

Driven by growth-oriented and technology-centric values, humanity's information-processing systems tend to prioritize solutions that are closely aligned with technological advancement and the promise of continued economic growth. As a result, costly and energy-intensive technological innovations are often favored, even when their effectiveness remains uncertain. This bias not only exacerbates existing environmental problems but also marginalizes more effective, low-cost, and ecologically sound alternatives, such as nature-based solutions (e.g., including those related to Indigenous and Local Knowledge systems) (Nguyen et al., 2025).

Market-driven models inherently favor patented technologies because they offer clear profit potential and commercial pathways for investors and corporations. As a result, innovation ecosystems are shaped less by environmental effectiveness and more by marketability and intellectual property considerations (Arora et al., 2016; Pries & Guild, 2011). This commercial logic underpins global funding priorities, reinforcing a self-perpetuating cycle in which capital flows toward technologies that promise returns, rather than those that deliver ecological resilience.

Conversely, Indigenous and Local Knowledge systems—often collective, orally transmitted, and context-specific—rarely conform to intellectual property regimes. Their absence of discrete ownership structures renders them incompatible with market-based funding frameworks (Mendes et al., 2020). Moreover, the transmission of Indigenous and Local Knowledge systems through intergenerational lived experience resists commodification and formalization, which limits their integration into dominant financial and governance systems (J. H. Nguyen et al., 2023). This misalignment ensures that even highly effective, community-based practices remain systematically excluded from formal funding and policy mechanisms (Bellamy & Osaka, 2020; Slavíková, 2019).

Institutional legitimacy further amplifies the structural bias toward high-tech solutions. Innovations endorsed by corporations, research institutions, and influential policy bodies tend to receive disproportionate media visibility and policy support (Drury et al., 2022). This media amplification reinforces public and political perceptions of technological interventions as inherently superior and more viable (Bellamy & Osaka, 2020; Dai et al., 2023). In contrast, Indigenous and Local Knowledge systems-based approaches, often rooted in oral traditions and embodied practices, remain largely invisible within formal epistemic structures (Gómez-Baggethun, 2022). The dominant knowledge systems privilege written documentation, peer-reviewed publications, and standardized metrics, sidelining Indigenous knowledge that does not adhere to these conventions (Nesterova, 2020). As a result, Indigenous and Local Knowledge systems remain excluded not only from financial resources but also from legitimacy in mainstream climate and economics discourse and policy formulation (Mendonça et al., 2021).

Despite the substantial financial and political support afforded to technological interventions, many of these approaches demonstrate limited real-world effectiveness. For instance, Carbon Capture and Storage (CCS) technologies, long heralded as critical to decarbonization strategies, face serious implementation barriers. These include prohibitively high costs, energy-intensive operation, and unresolved risks such as CO_2 leakage (Deng et al., 2017; Mahjour & Faroughi, 2023). In addition, the integration of CCS with Enhanced Oil Recovery operations may paradoxically extend the lifespan of fossil fuel industries, thereby delaying essential transitions to low-carbon energy systems (Leung et al., 2014; Sovacool, 2021; Yasemi et al., 2023). This phenomenon, known as technological lock-in, diverts resources and policy attention away from more transformative solutions like decentralized renewables or ecological restoration (de Coninck & Benson, 2014).

A similar pattern is also found in climate change geoengineering proposals, which aim to slow ice loss through interventions such as underwater barriers and cold-water pumping. While theoretical models suggest potential benefits under ideal conditions, these interventions remain fraught with substantial logistical and implementation challenges (Moore et al., 2018; Sutter et al., 2023; Wolovick & Moore, 2018). The complex and nonlinear dynamics of ice sheet systems make the translation of these theoretical benefits into real-world outcomes problematic and highly uncertain (Moore et al., 2018; Wolovick & Moore, 2018). Recent evidence indicates that even under ideal circumstances, such interventions would be insufficient to prevent the collapse of the West Antarctic Ice Sheet in high-emission scenarios (Sutter et al., 2023). This limited potential stems in part from persistent subsurface ocean warming, which continues to undermine ice shelf stability despite reductions in surface temperatures (Alevropoulos-Borrill et al., 2024). Additionally, while some geoengineering approaches attempt to slow ice loss by modifying meltwater flow or constructing physical barriers, they must be rigorously assessed to avoid inducing unintended feedback mechanisms that could accelerate, rather than mitigate, ice loss (Lockley et al., 2020; MacAyeal et al., 2024; Moon, 2018).

In addition to limited effectiveness, these interventions carry significant ecological and geopolitical risks. The construction of artificial islands or large-scale water pumping systems could disrupt marine ecosystems, alter subglacial hydrology, and affect ocean circulation patterns (Field, 2025; MacAyeal et al., 2024). The transboundary nature of these potential effects raises complex governance challenges, particularly around environmental justice and international accountability (Moore et al., 2021; Sovacool, 2021; Tuana et al., 2012). Developing nations, which are often most vulnerable to sea-level rise but least responsible for emissions, could disproportionately suffer the consequences of poorly regulated geoengineering experiments.

Despite growing evidence of their limitations and associated risks, technologically intensive climate solutions continue to dominate policy agendas, media narratives, and investment flows. This systemic imbalance is particularly evident in public spending patterns. Over the past decade, governments—including those of the U.S., Canada, Norway, and the European Union—have collectively allocated more than $20 billion to the development of CCS technologies, with an additional $200 billion pledged through future support mechanisms such as tax incentives, grants, and innovation programs (Oil Change International, 2023). However, the mitigation outcomes achieved thus far remain disproportionately low relative to the scale of these investments. As of late 2023, only approximately 65 million tonnes of CO_2 per year were being captured across roughly 41 commercial facilities, amounting to less than 0.2% of global annual CO_2 emissions (Hanbury, 2024).

This misallocation of resources underscores a deeper systemic inefficiency: the prioritization of technologically sophisticated, capital-intensive solutions over more ecologically attuned and socially embedded alternatives. Nature-based solutions—such as wetland restoration, reforestation, and Indigenous land stewardship—not only offer proven mitigation and adaptation benefits but also strengthen ecosystem resilience, biodiversity conservation, and community well-being. However, their integration into formal policy remains hindered by entrenched economic and epistemological biases in humanity's information-processing system.

3.4 Bubble formation and immiserating growth

Among the many costly and often inefficient market- and technology-oriented climate solutions, a few have demonstrated measurable potential to reduce emissions while supporting economic growth through the green growth model. A prominent example is the electrification of transportation and energy systems. Electric vehicles (EVs) are central to this transition, offering the promise of lowering tailpipe emissions and facilitating the decarbonization of mobility systems (Buberger et al., 2022; UNEP, 2024). Empirical research suggests that substituting internal combustion engine vehicles with EVs could reduce emissions by approximately 22-40%, especially when powered by low-carbon or renewable electricity sources (Farzaneh & Jung, 2023).

At the core of this transformation lies battery technology, which supports both electric transportation and renewable energy storage. The resulting surge in battery demand has spurred rapid industry growth, attracting large-scale public and private investment and becoming a strategic focus of national industrial and energy policies (FCAB, 2021). In response, major economies have poured capital into gigafactory construction and mineral extraction projects to secure supply chains and strengthen competitive positioning within the emerging green economy.

Yet this rapid expansion has produced unintended consequences. Oversupply of key battery materials - including lithium, nickel, and cobalt - has led to dramatic price declines. By late 2024, nickel prices had plunged to roughly $15,300 per metric ton, marking an 85% drop from their 2022 peak (Belder, 2025). Lithium, which previously soared to around $80,000 per ton, fell to approximately $13,000, while cobalt prices dropped from $82,000 to around $24,900 over the same period (Andy Home, 2024; Lombardo et al., 2025; Mehdi, 2024). These steep declines have triggered widespread financial distress across the sector, forcing numerous companies to downsize, halt production, or file for bankruptcy.

For example, Australia's Nickel West - once seen as a key player in the battery supply chain - suspended operations in late 2024 due to unmanageable losses (Andy Home, 2024). In Indonesia, several nickel smelters reduced or ceased production as ore shortages and financial instability gripped their Chinese investors. A notable case is the $3 billion Chinese-backed Gunbuster Nickel project, which drastically scaled back operations amid the collapse of its parent firm (Spence & Cang, 2025).

The environmental costs associated with this electrification push are significant. In pursuit of material mining and processing, vast tracts of tropical rainforest - among the most carbon-dense and biodiverse ecosystems globally - have been cleared (Ruehl & Dempsey, 2023; Wahyono et al., 2024). This deforestation not only releases large amounts of stored carbon but also threatens irreplaceable habitats and endemic species, effectively undermining the climate benefits of EV adoption. The mining and processing of nickel, particularly in Indonesia, also pose significant pollution risks. Laterite nickel ore requires energy-intensive refining, and its exposure to rain and air can generate acidic runoff that contaminates rivers, groundwater, and marine ecosystems (Sugiono et al., 2024). In some regions, the visible consequences include rivers turned red from sediment, dwindling fish stocks, and degraded agricultural land (CREA, 2024; Sugiono et al., 2024). Waste disposal practices such as deep-sea tailings placement further endanger marine biodiversity (Stauber et al., 2022), while the heavy reliance on coal-fired power in smelting operations exacerbates local air pollution, ironically in the production of "clean" energy technologies (Mervine et al., 2025).

Facing growing scrutiny, mining corporations, battery manufacturers, and automakers have issued sustainability pledges. These include commitments to land rehabilitation, biodiversity offsets, and reductions in carbon intensity through renewable energy integration (Devenish et al., 2022; Kurmala, 2024). Yet as material prices fall and margins tighten, these promises are increasingly at risk. Markets are flooded with low-cost supply from producers with minimal environmental safeguards, while companies committed to higher sustainability standards are being priced out or driven into insolvency. This erosion of financial stability compromises restoration plans. For instance, firms that pledged to reforest after clearing rainforests may be unable to deliver on such promises if they are operating at a loss or facing bankruptcy. In many cases, environmental restoration is only seriously considered after profitable extraction is complete. This raises the risk that depleted mining sites will be abandoned, leaving local communities and governments to deal with contaminated water, infertile land, and irreversible biodiversity loss, including the extinction of endemic species. The situation mirrors the phenomenon of immiserizing growth, where a boom in extractive exports leads not to prosperity but to ecological devastation and net economic harm (Bhagwati, 1969; Vuong, Nguyen, Tran, et al., 2025).

Indonesia's nickel industry provides a stark illustration of this dynamic. Between 2017 and 2023, nickel output rose from 358,000 to 2.2 million tons, securing more than half of the global market share (Home, 2025b). Nickel now accounts for roughly 10% of national exports, valued at over $30 billion, and supports tens of thousands of jobs (Lakshmi & Mariska, 2025). However, this dramatic increase in supply has intensified the global price decline, undercutting long-term profitability. Despite large-scale extraction and industrialization, overall revenues have fallen short of expectations, while environmental degradation has accelerated (Belder, 2025). As of 2024, the industry is sustained by 49 rotary kiln electric furnace (RKEF) smelters and five high-pressure acid leach (HPAL) facilities, with 35 additional RKEF and three HPAL plants under construction and 55 more processing permits issued (Lakshmi & Mariska, 2025). Yet this infrastructure expansion can create long-term ecological degradation and exacerbated economic liabilities, embodying the paradox of immiserating growth, where intensified economic activity generates deeper harms and diminished national well-being.

In the near term, a recovery in material prices seems unlikely, particularly as the EV industry itself faces mounting challenges. A striking case is Northvolt, once hailed as Europe's flagship EV battery manufacturer. Founded in 2016 by a former Tesla executive and backed by European automakers, Goldman Sachs, and the largest-ever EU green loan, the company filed for bankruptcy in Sweden in March 2025 after failing to secure further financing (Eddy, 2025; Report, 2024). These difficulties are not confined to Europe. In China - home to nearly two-thirds of global EV production and over three-quarters of EV batteries - similar signs of strain have emerged. Despite generous subsidies and favorable policies, the Chinese EV market has experienced intense price competition, eroding profitability. Between 2022 and 2024, average retail car prices in China dropped by 19%, even after the official end of government subsidies in 2022 (Cheng, 2025; Yang, 2023). Simultaneously, international trade tensions have escalated: the European Union has imposed tariffs of up to 38.1% on Chinese EVs, while the United States has raised tariffs on Chinese EVs from 25% to 100%, and on lithium batteries from 7.5% to 25% (Elliott, 2024; Iordache & Kiderlin, 2024). These pressures threaten to exacerbate China's oversupply crisis, with potential ripple effects across the global EV supply chain.

The global growth-oriented and technology-centric agenda has placed battery technology at the forefront of climate strategies, but an overreliance on a narrow set of techno-economic solutions is generating structural vulnerabilities. A narrow emphasis on electrification - absent concurrent investments in systemic transformation, ecological restoration, equitable governance, and long-term commercial viability - risks generating both environmental degradation and economic fragility. If left uncorrected, this trajectory may foster speculative economic bubbles and lead to immiserizing growth (Vuong, Nguyen, Tran, et al., 2025).

4. The necessity of a semi-conducting principle

The growth-oriented and technology-driven values of mainstream economics commodify nature by framing environmental decision-making through the lens of economic cost-benefit analyses. Within this paradigm, the preferred course of action is the one deemed most economically viable - that is, the option that maximizes net contributions to the economy after all projected costs and benefits are accounted for (Hanley et al., 2009). Consequently, governments, financial institutions, and corporations increasingly rely on economic assessments that are often deeply subjective, overlook ecological uncertainties, and fail to incorporate the risks of irreversible environmental degradation (Armstrong McKay et al., 2022; Eichner, 1983, 1985; Lenton et al., 2019; Lo, 2023; Richardson et al., 2023). This fosters the illusion that sustained economic growth is compatible with environmental protection, provided sufficient investment is made in advanced - yet frequently expensive, low-impact, and highly uncertain - technological solutions.

When certain technologies, such as renewable energy systems or electric vehicles, are identified as having potential, they often attract disproportionate investment. This overreliance on select technologies risks the formation of speculative economic bubbles and may lead to immiserating growth, particularly for countries that become dependent on volatile markets and resource-intensive supply chains. These systemic flaws expose the inherent vulnerabilities of artificial environmental protection systems - those predicated on economic optimization and technological substitution - making them increasingly fragile in the face of political instability or shifting market dynamics.

Influenced by the dominant paradigm of neoclassical economics, modern societies have long equated growth with monetary gain. As a result, policy strategies and business models are often designed to ensure that financial returns exceed economic costs. For governments, this manifests in cost-benefit analyses that routinely fail to capture ecological thresholds or irreversible damage. For businesses, where profitability is the bottom line, environmental costs are frequently perceived as financial losses. Consequently, firms tend to minimize these losses through lobbying, tax optimization, or by deploying greenwashing strategies, such as exploiting carbon credit schemes (Adi, 2018; Walker & Wan, 2012).

To address such systemic flaws, today's socio-economic systems must adopt the semiconducting principle of monetary and environmental value exchange (Vuong & Nguyen, 2024a). This principle ensures that environmental values can be converted into economic values, but not vice versa. In other words, while ecological contributions may be rewarded economically, monetary values are not allowed to define or diminish environmental worth. Achieving this requires a fundamental shift in how we conceptualize "growth" or "profitability." The redefined notion of growth must reflect this asymmetrical valuation (Vuong, 2021a):

$$NV = NMV + NEV$$

Where NV is the new notion of growth (or new Net Value), NMV is the normal Net Monetary Value, and NEV is the new notion of Net Environmental Value. Although both monetary and environmental values are recognized as legitimate within socio-economic systems, the semiconducting principle must be applied to prevent monetary values from compensating for the loss of environmental values. Under this principle, environmental values may be translated into monetary terms, but not the other way around. This asymmetrical, non-linear mechanism is designed to enhance the adaptability of human systems to Earth's ecological system, which is inherently marked by multiple disequilibria (e.g., planetary boundaries, climate, and ecological tipping points) (Armstrong McKay et al., 2022; Richardson et al., 2023). A clear example of the failure of the current system design is the current carbon trading system, which lacks the semiconducting property. As a result, it can be exploited to greenwash activities that are, in reality, environmentally destructive (Greenfield, 2023; Guizar-Coutiño et al., 2022; Jiang et al., 2025; West et al., 2020; West et al., 2023).

In contrast, a system grounded in the semiconducting principle would constrain the instrumentalization of environmental discourse for economic, political, or geopolitical gains. It would create the institutional and cultural conditions under which environmental sustainability is a precondition - not a byproduct - of sustainable development.

If nature is understood as the source of life, then the logical question arises: Why do we not strive to enrich this life source? The life source embodies value. Economics, at its core, is the discipline concerned with managing value in the most efficient and sustainable way. Following the foundational economic maxim that saving is the mother of all investment, the first step toward investing in the life-sustaining systems that support us must be saving them - that is, halting unsustainable exploitation. In this light, preventing environmental debt and ecosystem destruction becomes the highest-priority strategy for implementing the semiconducting principle. This includes halting deforestation, protecting biodiversity hotspots, and reducing overconsumption that fuels excessive resource extraction. As research has shown, preserving primary forests - irreplaceable carbon sinks and biodiversity reservoirs - is far more cost-effective than attempting post hoc restoration (Nelson et al., 2023).

The second priority strategy is amplifying effective, low-cost, and scalable solutions. This tier centers on nature-based solutions and Indigenous and Local Knowledge systems, such as regenerative agriculture, agroecology, and community-led conservation. These approaches not only offer superior ecological outcomes but do so at a fraction of the cost of industrial or top-down alternatives (Garnett et al., 2018). Finally, capital-intensive and technologically complex interventions - such as geoengineering, direct air carbon capture, and other high-risk innovations - should be used only as last-resort tools to address residual emissions or ecological damage that cannot be solved through the first two tiers. These solutions must be subjected to strict scrutiny and employed with caution, given their uncertain outcomes, high costs, and potential for unintended consequences.

In a socio-economic system governed by the semiconducting principle and the redefined notion of growth, all actors - including governments, businesses, and citizens - are incentivized to pursue forms of development that remain within planetary boundaries and actively contribute to the restoration, conservation, or enhancement of Earth's carrying capacity. Crucially, the business sector - while historically a primary source of environmental disruption - also possesses the capacity to drive transformative change. In a reformed system, businesses' *raison d'être* is no longer solely profit maximization but also ecological sustainability assurance. Firms would be incentivized not only to reduce environmental harms but to generate goods and services that actively enhance biocapacity and shrink ecological footprints.

To adopt and effectively implement the semiconducting principle, it is essential to cultivate individuals' Nature Quotients and foster a transition from the eco-deficit culture to the eco-surplus culture, both of which serve as foundational prerequisites. These concepts will be further elaborated in the following sections.

5. Building eco-surplus culture for humanity's continuity and progress

Effectively operationalizing the semiconducting principle requires more than institutional reform or technological innovation. It demands a socio-cultural transformation toward an eco-surplus culture. In this paradigm, environmental protection, restoration, and regeneration are not peripheral considerations or trade-offs but are foundational conditions for achieving long-term economic vitality, political stability, and social well-being (Vuong, 2021a). Environmental values are attributed to a higher probability of influencing decision-making than competing short-term interests, positioning ecological health as an existential condition rather than a constraint. This shift reframes environmental protection and restoration as a prerequisite for systemic resilience and intergenerational prosperity.

5.1 Nature Quotient cultivation

One of the foundational strategies for fostering eco-surplus culture is the cultivation of Nature Quotient (NQ) across society. NQ represents a form of intelligence that enables individuals to comprehend the complex and dynamic interactions of nature, position humans within such systems, and live harmoniously with and nurture the natural environment. Fundamentally, it refers to the capacity to perceive, process, and organize information about the intricate interconnections among various information-processing systems - such as humans, wildlife, ecosystems, and climate systems - as parts of a dynamic, interdependent whole (Vuong & Nguyen, 2025).

Cultivating a high NQ is essential to counteract the anthropocentric biases embedded in conventional thinking. It promotes a cognitive and cultural shift away from an extractive “eco-deficit” mindset toward a regenerative eco-surplus orientation. Individuals with high NQ demonstrate deep ecological awareness, engage in sustainable behaviors, and support a harmonious relationship between humans and nature. When developed at scale, NQ fosters a collective consciousness that positions ecological well-being as a fundamental prerequisite for human survival, well-being, and intergenerational continuity.

Among the most practical and impactful avenues for enhancing NQ is the reform of education systems. Integrating environmental literacy and sustainability principles across all levels of formal education equips younger generations with system-thinking capabilities and a deeper sense of empathy for nature. This, in turn, strengthens their cognitive, emotional, and ethical connections to the natural world. Several countries have taken significant steps in this direction. In India, environmental education has been mandated nationwide across formal schooling, following a Supreme Court directive that recognized environmental awareness as a fundamental necessity and directed the adoption of environmental education in the syllabus in all states and union territories (Gorana & Kanaujia, 2016). India adopted an “infusion” approach, integrating environmental topics across a range of disciplines - including science, social studies, mathematics, and language - while emphasizing real-world problem-solving and critical thinking. This approach underscores the importance of holistic thinking in environmental education, aiming to transcend fragmented, sector-specific perspectives by fostering multidisciplinary understanding and action (Gorana & Kanaujia, 2016).

Beyond formal curricula, direct and meaningful engagement with nature is essential for cultivating NQ. A growing body of research demonstrates that childhood experiences in natural settings are strong predictors of pro-environmental attitudes and behaviors in adulthood (Chawla, 1999; Dewey, 2021; Rosa et al., 2018; Yan et al., 2025). A comparative study of environmental activists in the U.S. and Norway found that the vast majority identified early outdoor experiences as the foundational source of their ecological consciousness (Chawla, 1999). Conversely, the absence of such experiences - often referred to as nature deficit disorder - can result in a disconnection from natural systems and constrain the formation of values related to nature (Beery et al., 2023; Louv, 2008; M.-H. Nguyen et al., 2023). To address this gap, educators and communities have launched initiatives aimed at reintroducing both youth and adults to the natural world. For example, “bioblitz” events invite schoolchildren to spend time in parks and natural areas identifying as many species as possible, offering many their first immersive encounter with local biodiversity (Himschoot & Children, 2017; Pollock et al., 2015). Similarly, outdoor classrooms, gardening programs, and citizen science projects - such as wildlife counts or water quality monitoring - enable participants to translate abstract environmental concepts into concrete, lived experiences (Askerlund & Almers, 2016; Green & Duhn, 2015; Wilson et al., 2025). These experiential learning models play a pivotal role in enhancing NQ. By facilitating direct interaction with ecological systems, they help individuals internalize the principles of interdependence and develop a more intuitive, values-based understanding of environmental sustainability.

Cultivating NQ also necessitates the shaping of cultural products that emphasize harmony with nature. Popular media, storytelling, and artistic expression play a crucial role in influencing how societies perceive and relate to the natural world. For instance, the impact of natural history documentaries - such as the BBC's Blue Planet series - demonstrates the potential of media in fostering ecological awareness and preferences (Dunn et al., 2020; Hynes et al., 2021). Similarly, many Indigenous cultures have long embedded ecological wisdom in oral traditions, spiritual practices, songs, and stories (Fletcher et al., 2021). These cultural products teach interconnection, stewardship, and respect for nature across generations (Bohensky et al., 2013; McAllister et al., 2023; Ulluwishewa et al., 2008). Contemporary educational and environmental communication efforts can learn from such traditions by integrating art, literature, and multimedia content that convey ecological complexity and nurture connection and empathy for non-human life (Nguyen, 2024a; Reason & Gillespie, 2023; Vuong & Nguyen, 2023a, 2023b). The overarching goal is to position ecological literacy as a foundational competency - on par with reading, writing, and numeracy - thereby establishing it as a cultural norm. An ecologically literate society is more likely to avoid unsustainable practices, support necessary changes, and co-create an eco-surplus culture rooted in long-term resilience and regeneration.

Nature-based cultural products also reflect deep cognitive and cultural interactions with the environment, not as a passive backdrop, but as a co-creator of human knowledge, values, and moral frameworks. These products can serve as powerful vehicles for cultivating collective ecological intelligence, or what may be termed "collective NQ" (Vuong & Nguyen, 2025). A prominent example is the *Daodejing* by Laozi (Lao Tzu, 老子), the foundational text of Daoism, alongside the writings of later Daoist thinkers such as Zhuangzi (Zhuang Zhou, 莊子). These philosophical works have deeply influenced East Asian cultural heritage across China, Japan, Korea, and Vietnam. Daoist philosophy and thought have profoundly influenced diverse realms of cultural expression - including literature, visual arts, architecture, calligraphy, music, martial arts, and traditional medicine - each reflecting a deep-seated emphasis on the harmonious interplay between humans and the natural world. At the heart of this worldview lies the principle of mindful coexistence with all living beings and the aspiration to comprehend their “true inborn nature” (Cooper, 2014; Laozi, 1868).

As NQ is cultivated more broadly across society, it lays the groundwork for the emergence of an eco-surplus culture. Individuals with high NQ typically exhibit a deep appreciation for biodiversity, an understanding of the long-term consequences of environmental degradation, and a strong sense of ecological responsibility. This shift in mindset - from anthropocentric indifference to environmental stewardship - represents a critical bottom-up driver of broader socio-cultural transformation. In practical terms, fostering NQ results in the emergence of citizens, scientists, policymakers, and business leaders who are systems thinkers and ecologically conscious decision-makers. These individuals are more likely to design, support, and demand solutions aligned with the principles of an eco-surplus paradigm. As such, investing in NQ - through education, community-based initiatives, and public engagement campaigns - is a strategic precursor to shifting societal values. It builds the cognitive foundation required to redefine societal notions of progress, success, and legacy in ecologically meaningful terms.

5.2 Policy pathways and social initiatives to foster an eco-surplus culture

Transitioning from an eco-deficit to an eco-surplus culture - one that treats ecological health as the foundation of human well-being - necessitates coordinated efforts across governance, economic systems, and grassroots action. This subsection outlines how each of these dimensions can catalyze this cultural transition and reinforce the semiconducting principle of value exchange between environmental and monetary values.

Transitioning to an eco-surplus culture requires bold policy reforms that integrate environmental sustainability into decision-making, public budget planning, and the definition of national prosperity. A crucial first step is redefining “growth” and “profit” within policy frameworks. Traditional economic growth metrics must be broadened to include Net Environmental Value (NEV) alongside Net Monetary Value (NMV), establishing a new Net Value (NV = NMV + NEV) paradigm (Vuong, 2021a; Vuong & Nguyen, 2024a). In practice, this involves developing national accounting systems that properly value ecosystem services and biodiversity, ensuring that policy success is assessed not only by GDP but also by improvements in natural resources and resilience. For instance, several countries are investigating a Gross Ecosystem Product (GEP) to quantify nature’s contributions to people (Ouyang et al., 2013; Zheng et al., 2023). By internalizing NEV, policies can ensure that environmental costs are not externalized or traded off for short-term economic gains.

Several forward-thinking governments have begun to adopt well-being budgets and "beyond GDP" frameworks that place ecological and social health at the center of investment and funding decision-making (Bartos, 2022; Hoekstra, 2019). New Zealand stands out as a pioneer in this space. Its inaugural Wellbeing Budget in 2019 garnered international recognition for prioritizing citizens' well-being and environmental values as core policy goals. The New Zealand Treasury now utilizes a Living Standards Framework, which incorporates a broad range of indicators - including environmental amenity, subjective well-being, natural environment, social cohesion, human capability, etc. - when advising on investments and outcomes (New Zealand Government, 2021). As former Prime Minister Jacinda Ardern aptly stated, "The purpose of government spending is to ensure citizens' health and life satisfaction, and that - not wealth or economic growth—is the metric by which a country's progress should be measured. GDP alone does not guarantee improvement to our living standards […]" (Walker & Tolley, 2019).

This approach is gaining traction globally. The Wellbeing Economy Governments (WEGo) partnership - comprising Scotland, Iceland, New Zealand, Wales, and Finland, with Canada actively participating - facilitates the sharing of best practices in designing budgets and policies that account for human wellbeing, including environmental sustainability (Janoo et al., 2021). Bhutan, long recognized for its alternative development model, continues to guide policy-making and spending decisions using its Gross National Happiness (GNH) index. The GNH framework is grounded on four fundamental pillars, one of which is environmental conservation. At the municipal level, Amsterdam offers a compelling example of urban-scale innovation. The city has adopted Doughnut Economics - a model developed by economist Kate Raworth - as a strategic compass for policymaking. This framework aims to ensure a high quality of life for all residents while staying within planetary boundaries (Florian, 2024; Raworth, 2018). Collectively, these pioneering fiscal policies and planning frameworks operationalize an eco-surplus mindset. They move beyond symbolic and performative environmental actions to embed ecological well-being as a foundational asset and a core success metric, rather than treating it as a secondary concern or afterthought.

Strong environmental laws and enforcement should focus on achieving direct ecological outcomes. This includes robust protections for primary forests, wetlands, and biodiversity hotspots, with a clear policy of no net loss—or ideally,

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net gain - of critical ecosystems and biodiversity, particularly those that are endangered. Research indicates that preventing ecosystem loss is far more effective and cost-efficient than attempting to restore ecosystems afterward (Bloomgarden, 2022; Cook-Patton et al., 2021). Policies must prioritize halting the ongoing degradation of ecosystems before addressing other measures, such as improved land management and restoration, which can yield lasting benefits. Importantly, environmental regulations should enforce the semiconducting principle: ecological degradation should not be offset simply by monetary payments or permits. Policies like carbon pricing and cap-and-trade should be redesigned to reward actual emissions reductions and ecosystem protection, while preventing the purchase of permits to pollute. The shortcomings of the current carbon-offset model highlight this need. The existing carbon trading system lacks the semiconducting property, allowing companies to balance continued emissions by purchasing inexpensive offsets. This opens the door to greenwashing; investigations have shown that over 90% of rainforest carbon offsets under the leading standard were essentially "phantom credits," with no actual carbon reductions (Greenfield, 2023).

Beyond environmental protection, policymaking for an eco-surplus culture should embed sustainability principles across all sectors. This involves conducting environmental impact assessments and planetary boundary checks for major projects, implementing climate and biodiversity stress tests for infrastructure and urban planning, and incorporating indigenous and local knowledge into policy design. It also requires prioritizing long-term and intergenerational thinking in governance. By crafting laws that reflect our interconnectedness with nature, governments can create the norms and incentives that foster an eco-surplus culture.

One transformative approach is the legal recognition of nature's intrinsic value and rights. In 2017, New Zealand set a global precedent by granting legal personhood to the Whanganui River in response to long-standing Māori advocacy. The river was recognized not merely as a resource, but as a spiritual ancestor with its own rights and agency - a move grounded in the Indigenous worldview of *te ao Māori*, which sees rivers, lands, and people as interconnected members of one family (Evans, 2024). This legal shift was also extended to other natural entities, including Te Urewera forest and Mount Taranaki, reinforcing a governance model that redefines nature as a partner rather than property. Similar legal innovations have emerged in other parts of the world. Ecuador's 2008 Constitution was the first to formally enshrine the Rights of Nature - referred to as *Pachamama* or Mother Earth - while Bolivia followed with its Law of the Rights of Mother Earth, mandating integral respect for nature's existence, mantainance, and regeneration of its life cycles, structures, functions, and evolutionary processes (Berros, 2015). By codifying respect for ecosystems, these legal frameworks promote an eco-surplus ethic at the highest institutional levels. They signify a paradigm shift: from anthropocentric exploitation to ecologically grounded co-existence, recognizing that non-human life possesses value independent of its economic utility and that human flourishing depends on living within planetary boundaries.

Public finance and fiscal policy are powerful tools for cultivating an eco-surplus culture. One emerging approach is green budgeting, which integrates environmental criteria into government budgeting processes. Rather than funding "green" projects in isolation, green budgeting incorporates environmental impacts into all aspects of fiscal planning, analyzing how each spending or tax decision affects nature and aligning fiscal priorities with sustainability goals (Kaiser & Lelong, 2025). By reorienting fiscal planning in this way, governments explicitly prioritize ecological well-being alongside economic growth, thus operationalizing the semiconducting principle within monetary flows. Realigning subsidies and taxes is also a crucial component. Currently, many governments continue to allocate significant funds to environmentally harmful subsidies, inadvertently incentivizing eco-deficit behaviors. An eco-surplus fiscal strategy would phase out these "brown" expenditures and redirect funds toward investments that promote ecological health and human well-being. For instance, Indonesia recently cut fossil fuel subsidies by approximately $10 billion and redirected those funds toward renewable energy and other climate initiatives (Kaiser & Lelong, 2025). Such positive incentives can reward eco-surplus efforts, like payments for ecosystem services, tax breaks for renewable energy and circular economy businesses, grants for community conservation projects, etc. These efforts can translate ecological value into economic reward, reinforcing behavior that strengthens our life-support systems.

Fiscal planning must also address the economic risks posed by environmental degradation, from climate-related disasters to the collapse of vital ecosystems. Incorporating climate and biodiversity risks into sovereign credit ratings, central bank stress tests, and development plans will drive financial systems to favor sustainability. However, the economic valuation of ecosystem functions should be applied with extreme caution. While forecasts of economic losses due to environmental degradation may seem dire, many experts argue these estimates are still significantly understated and fail to capture the full scope of ecological catastrophe (Beuret, 2021). Analyses from organizations such as the Institute and

Faculty of Actuaries (UK) and Carbon Tracker reveal that mainstream economic models consistently underestimate the true cost of climate change. This underestimation stems from critical omissions, such as ecological tipping points, precipitation variability, and the flawed assumption that indoor economic activities remain unaffected by environmental change. Such flawed valuation frameworks risk trivializing irreversible losses - like biodiversity collapse and human suffering - by reducing them to monetary units adjustable by central bank policy. Furthermore, research by Franta (2022) and Brulle (2023) reveals how fossil fuel industry coalitions have funded biased economic analyses to obstruct climate policy.

Fostering an eco-surplus culture requires active engagement from the private sector as a constructive force for environmental protection and restoration. Under the prevailing eco-deficit paradigm, many business practices have historically externalized environmental costs in the pursuit of profit, contributing to ecological degradation and long-term systemic risk. In contrast, emerging regenerative and circular economic models offer a transformative alternative. Some companies are now adopting net-zero or even net-positive targets, striving to restore more environmental value than they consume. Industries such as fashion and electronics need to explore circular design principles to reduce waste and extend product life cycles. Public policy can play a catalytic role in accelerating this transition by creating enabling conditions for eco-surplus innovations and discouraging those that deplete natural capital. Examples include research grants for nature-based solutions, tax incentives for low-impact manufacturing, and public procurement policies that prioritize cradle-to-cradle certified products.

Multi-level and inclusive governance is also critical for achieving eco-surplus outcomes. Environmental issues span local to global scales, so a polycentric approach—coordinating efforts at the city, provincial, national, and international levels—is more effective than top-down control alone. For example, while international treaties set broad goals (e.g., the Montreal Protocol or the Kunming-Montreal Global Biodiversity Framework), progress often depends on local authorities and communities enforcing protections on the ground. Mechanisms for vertical integration, such as "nationally determined contributions" feeding into global climate goals or subnational conservation commitments, help align efforts. At the same time, horizontal networks facilitate knowledge sharing, peer learning, and accountability (e.g., cities sharing best practices through the C40 global network or indigenous peoples participating in UN environmental forums). An eco-surplus governance system explicitly values the knowledge and rights of Indigenous peoples and local communities, recognizing them as key stewards of biodiversity and the environment and partners in policymaking. Including these voices - through formal seats in decision-making bodies, Free, Prior, and Informed Consent processes for projects, and community-led resource management - ensures that governance is grounded in on-the-ground realities and justice (Hanna & Vanclay, 2013).

While top-down measures are essential, grassroots movements are equally crucial for driving socio-cultural transitions. One of the most influential aspects of grassroots action is its ability to shift social norms and raise public awareness. The rapid rise in environmental consciousness in recent years can largely be attributed to bottom-up movements. What makes these movements effective is their emphasis on collective action: diverse individuals uniting around a common cause and applying sustained pressure on governments and corporations to drive change (The Goldman Environmental Prize, 2021). However, radical activism, such as art vandalism and road blockades, should be avoided, as it can produce adverse outcomes and diminish public support for environmental causes (Vuong, Nguyen, Duong, et al., 2024). Transformations risk destabilizing or even damaging the existing organizations and social and economic structures that sustain the lives of many if the process is not managed through thoughtful consideration, learning, and adaptation. Social resistance to change and resulting conflicts are inevitable, but managing these tensions is vital (Abson et al., 2017). Intensified conflicts exacerbate, rather than resolve, climate challenges. Therefore, alongside raising awareness and pressuring political and economic systems to address climate change, activists should also focus on facilitating the process of structural transformation and social transitions to minimize their costs (Vuong, Nguyen, Duong, et al., 2024).

Community-based conservation is another vital grassroots approach that fosters the eco-surplus culture and reinforces the semiconducting principle. Across the globe, local groups are leading initiatives to restore degraded lands, protect wildlife, and manage resources sustainably. These projects often demonstrate innovative strategies that formal institutions can learn from. For example, community forestry initiatives in Nepal and Mexico have shown that local populations can effectively manage forests to balance economic needs with ecosystem health (Baynes et al., 2015; Buckingham & Ellersick, 2015; Ellis et al., 2017). Supporting and scaling such community-led efforts - through micro-grants, land rights, and capacity-building - can help spread the eco-surplus practices at the grassroots level. When communities directly benefit from conservation - whether through secure livelihoods, ecotourism, or improved ecosystem services - it reinforces the idea that ecological value enhances human value, rather than replacing it.

Through the lens of GITT, socio-cultural transitions toward an eco-surplus culture can be understood as a series of granular interactions - an accumulation of decisions and behaviors across multiple levels (individual, group, institution, nation, and global) that collectively shape humanity's information-processing system. By integrating ecological consciousness, ethical considerations, and long-term thinking into each of these interactions, we enhance the probability that emergent outcomes will lean toward sustainability rather than collapse.

At its core, the eco-surplus culture resonates with the philosophy of the *Daodejing* (Laozi, 1868). Resilient socio-economic growth should arise naturally, rather than being forced or rigidly imposed. Artificial mechanisms, such as carbon trading and overemphasizing the role of electrification, are often imposed with force. In the *Daodejing*, the concept of “letting go” is not about discarding, but about relinquishing stubbornness, coercion, and actions that defy the natural flow of life. It advocates for allowing nature to find its own path, which in turn imparts wisdom to us. Cultivating NQ and fostering eco-surplus culture to harness the power of serendipity is one such path. When humanity places environmental values at the foundation of its existence - prioritizing ecological sustainability, well-being, and generational continuity - people will naturally come to recognize the inherent value of nature. This recognition will foster a genuine desire for environmental preservation and restoration, thus creating a demand for actions that promote these goals. Such desire serves as the essential condition for humans to leverage serendipity in discovering and applying nature-based innovations and solutions.

In addition to fostering valuable discoveries and innovations, an eco-surplus culture helps individuals recognize the multifaceted values of nature through various pathways, ultimately shaping nature and its vital elements into “objects of care” (He & Silliman, 2019; Nguyen, Duong, et al., 2024; Vuong, La, et al., 2025b; Wang et al., 2018). These realizations often unfold through non-technological “serendipitous moments,” where individuals unexpectedly recognize new values in nature. These moments facilitate the formation and internalization of knowledge and values that support environmental protection and restoration, guiding actions and decisions that align with these ideals (Nguyen, 2024b; Otero et al., 2020; Vuong, 2022). These “serendipity moments” are integral to the cultivation of humanistic values that include a profound love for nature. As a result, individuals are naturally inclined to explore new lifestyles that minimize negative environmental impacts, contributing to preservation and restoration (Vuong, La, et al., 2025b). Examples include zero-waste communities, local food cooperatives, urban habitat gardening, citizen science initiatives focused on species monitoring, and artistic/cultural expressions of biophilia. Such micro-changes often catalyze larger societal shifts. Each successful local initiative serves as proof of concept that living with an eco-surplus mindset is not only feasible but also rewarding, inspiring others to adopt similar practices.

In this context, markets and technological tools can be viewed as instruments that optimize humanity's information-processing capacity. The impacts - whether positive or negative - of these tools are contingent upon the values that drive their application. When market and technological solutions arise from these natural desires, rather than being imposed through coercion, they can naturally contribute to the emergence of the semiconducting principle. This is analogous to how society can break free from the chains of slavery, where human life and dignity are commodified. The more society internalizes environmental values into its mindset, the less control and enforcement will be needed. Ultimately, a resilient environmental protection system will emerge naturally through the interactions of individuals, businesses, institutions, and governments.

6. Overcoming challenges for an eco-surplus culture

From the perspective of GITT, the transition from an eco-deficit to an eco-surplus culture requires the introduction of a new set of information and values to humanity's information-processing system. This shift initially generates an increase in entropy, expressed as uncertainty and disruption across established socio-cultural and political patterns, norms, and structures. To mitigate this entropy, the interactions and systemic relationships that shape how individuals live, work, and connect within society need to be transformed to ensure long-term ecological sustainability. Yet, the emergence of this new order inevitably confronts various natural filters that function based on the benchmarks of a dominant preexisting growth-oriented and technology-centric values.

Perhaps the most immediate and tangible challenges to advancing an eco-surplus culture lie in managing the economic and social trade-offs inherent in transitioning away from the growth-centric model. The contemporary global economy is structurally predicated on continuous growth - rising GDP, expanding production, and accelerating consumption - as a condition for maintaining macroeconomic stability. Abrupt deviation from this model, if not carefully organized, risks triggering economic dislocation and social disruption. Employment, livelihoods, and government revenues are deeply intertwined with the expectation of growth; economic stagnation or contraction can lead to surging unemployment and declining fiscal capacity, jeopardizing essential public services such as healthcare, education, and welfare provision.

This presents a critical dilemma: how can humanity meaningfully reduce its ecological footprint without precipitating short-term hardships, particularly among vulnerable populations? Some scholars and practitioners have proposed degrowth or post-growth strategies for affluent societies, advocating for a deliberate reduction in material throughput and a reorientation of societal goals beyond GDP. However, even proponents of these frameworks acknowledge the risks of poorly executed transitions. For example, a scenario in which a nation abruptly curtails industrial activity and consumption could resemble the case of Austeria village: shuttered factories, widespread job losses, and escalating social unrest (Hoffman, 2024). In such instances, while environmental degradation may decline, the socio-economic distress can erode public support for sustainability, fueling political backlash and undermining long-term ecological objectives. These dynamics underscore the importance of careful calibration, ensuring that the timing, pace, and accompanying measures (such as job guarantees, social protection, and retraining programs) are thoughtfully designed and equitably distributed.

Transitioning away from a growth-centric economic model confronts deep-seated cultural norms and structural dependencies. Resistance emerges from industries and consumers embedded in the prevailing paradigm of perpetual production and consumption. Businesses that rely on high-volume sales—such as those in fast fashion, consumer electronics, or disposable goods—are particularly vulnerable to policies promoting sufficiency, reuse, or circularity (Nguyen, Nguyen, et al., 2024). Understandably, many of these firms actively lobby against measures that would curb consumption. On the consumer side, especially in affluent societies, behavioral inertia and lifestyle expectations present additional hurdles. People may resist giving up conveniences and habits (e.g., frequently buying new gadgets and fast travel) if alternatives are not appealing or if sufficiency is perceived as austerity. A notable recent example is the post-COVID-19 emissions rebound. Although the pandemic initially sparked optimism about the prospect of a “green recovery” - with targeted stimulus packages potentially accelerating investments in clean energy infrastructure - the actual outcomes diverged from these expectations (Chen et al., 2020; Dafnomilis et al., 2022). The pent-up consumer demand for travel, goods, and services drove a sharp resurgence in energy consumption (Chen et al., 2024; Dao et al., 2024;

McKinsey & Company, 2024). By 2022, global CO_2 emissions had not only rebounded but surpassed pre-pandemic levels (Liu et al., 2023).

Managing this socio-economic transition requires careful sequencing and strategic design. Central to this process is a redefinition of success, prosperity, and legacy, as advocated by the semiconducting principle, along with the adoption of alternative metrics that move beyond conventional measures such as GDP - examples include the Wellbeing Budget and Gross National Happiness. These metrics can reorient public policy toward fulfilling fundamental human needs, even in the absence of traditional economic growth. In the early stages of transition, reforms should follow three strategic priorities aligned with the semiconducting principle:

1. Safeguard existing ecosystems to prevent the accumulation of environmental value debts and irreversible ecological losses that cannot be offset monetarily.
2. Scale up effective, low-cost, and environmentally compatible solutions—particularly those that generate employment while operating within the Earth's regenerative capacity—to facilitate labor transitions from high-impact sectors to environmentally sustainable industries.
3. Reserve capital-intensive and technologically complex interventions for addressing challenges that cannot be resolved through the two former strategies, ensuring that such measures are employed as a last resort rather than a default approach.

Redefining the public's imagination of success, prosperity, and legacy requires the cultivation of NQ - an intelligence that helps integrate environmental values into individuals' and society's understanding of growth and profit. This process can begin by fostering awareness of how people's lives and their "objects of care" are increasingly vulnerable to climate change and ecological disruption (Wang et al., 2018). However, a significant barrier to this effort stems from deeply entrenched resistance to climate change mitigation. Decades of climate science denial and the widespread dissemination of misinformation have cultivated enduring public skepticism and apathy, which continue to obstruct effective policy implementation (Gounaridis & Newell, 2024; La et al., 2024). A recent study documents the rapid expansion of a global network comprising think tanks, research institutes, trade associations, foundations, and affiliated organizations that actively oppose climate science and policy. Over the past 35 years, the number of countries hosting at least one of these "counter-climate" organizations has more than doubled, with such groups now present in at least

51 nations, strategically coordinating efforts to delay or derail climate-related legislation and international cooperation (Furuta & Bromley, 2025).

Even among those who acknowledge the reality of climate change, a subtler obstacle emerges in the form of techno-optimism. Prominent among so-called ecomodernist thinkers is the belief that environmental problems can be addressed within the existing economic and institutional paradigms, primarily through technological innovation, without the need to confront systemic issues such as consumerism or growth dependency. Their credo - that "more technology" and "more modernity" can resolve the unintended consequences of modernity itself - champions tools such as renewable energy, carbon capture, geoengineering, and artificial intelligence for efficiency gains (Bove, 2021). While these technologies are undeniably important, they are often treated as panaceas. This mindset fosters an overreliance on speculative or high-risk solutions (e.g., large-scale geoengineering) while downplaying the urgency of behavioral change and cultural transformation. In doing so, it challenges the formation of eco-surplus values and the development of a societal ethos grounded in harmony with nature rather than dominance over it.

Moreover, the redefinition of benefits and growth can encounter resistance from powerful actors who derive substantial benefits from the existing growth-oriented, eco-deficit system. This system has enabled the emergence of networks of vested interests - including fossil fuel corporations, agribusinesses, mining conglomerates, and their political allies - whose economic and political power is intimately tied to the continued extraction and commodification of nature (Diesendorf, 2025). These actors frequently engage in practices of state capture, leveraging lobbying, campaign financing, and the revolving door between industry and government to influence policy in their favor. Consequently, environmental regulations and sustainability initiatives that threaten their financial interests are frequently weakened, delayed, or obstructed entirely (Diesendorf, 2025). These entrenched actors play a central role in maintaining the growth-centric status quo, constituting a significant structural barrier to sustainability transitions. Their continued influence reinforces systemic inertia, impeding the cultural and policy shifts necessary to build an eco-surplus culture and foster the semiconducting principle.

Political resistance to sustainability transitions is also embedded in the short-term orientation of electoral politics (Avelino et al., 2016; Hess, 2014). Democratic governments often hesitate to implement robust environmental policies due to concerns over voter backlash or perceived threats to national economic competitiveness. Incumbent industries frequently amplify these concerns by warning of job losses or economic downturns, narratives that resonate with politicians focused on reelection and short-term approval. As a result, climate policy is frequently constrained by a logic of incrementalism, wherein modest, non-disruptive measures are favored over the transformative actions required to address ecological crises at scale.

In the prevailing paradigm of eco-deficit culture, climate change and environmental protection agendas are frequently weaponized - used as strategic tools, bargaining chips, or leverage in international diplomacy, trade negotiations, and domestic political contests (Vuong et al., 2023). This weaponization of environmental agendas undermines the consistency and credibility of climate policies, leading to fragmented and short-sighted decision-making that often sacrifices long-term effectiveness for immediate political gains (Thomas & Warner, 2019). As a result, environmental commitments may appear "ephemeral" and unreliable in the eyes of the international community, further exacerbating social inequality and geopolitical tensions. Moreover, the line between genuine environmental concern and strategic political maneuvering becomes increasingly blurred, raising critical questions about the authenticity, legitimacy, and moral integrity of climate-related actions. This ambiguity makes it difficult to distinguish between sincere efforts and those driven by ulterior motives, thereby eroding the mutual trust necessary for collective climate action (Vuong et al., 2023).

The instability and unreliability of U.S. climate commitments illustrate such consequences of weaponizing climate change and environmental protection agendas. Scientists, particularly those attuned to the urgent risks of climate change, have been drawn into partisan disputes, raising concerns about the erosion of scientific neutrality and credibility. During the 2020 U.S. presidential election, leading scientific journals such as *Nature* and *Science* took the unprecedented step of publicly endorsing Joe Biden over then-President Donald Trump (Editorial, 2020; Malakoff, 2020). While well-intentioned, this move transformed segments of the scientific community - especially those associated with climate science - into perceived political actors, blurring the boundary between objective expertise and partisan advocacy.

Such developments carry long-term risks. Political power is transient, and the scientific community may face significant challenges in securing its status, influence, and resources under administrations that consider science and climate change agendas as "weapons" of political opponents. This was evident through the withdrawal from the Paris Agreement, extensive regulatory rollbacks, funding cuts, and substantial disengagement from international frameworks such as the

Net-Zero Banking Alliance during the administration of President Trump. These shifts not only weakened climate governance but also contributed to a broader erosion of public trust in science. Recent surveys reflect this troubling trend: public confidence in the societal benefits of science has markedly declined in the U.S. Since 2016, the proportion of Americans who believe science has a positive impact on society has dropped from 67% to 57%, while the percentage of those viewing science negatively has doubled from 4% to 8%. Over one-quarter of respondents now report little or no trust in scientists to act in the public interest—up from just 12% in April 2020. Although this erosion of trust spans political affiliations, it is particularly pronounced among Republicans, nearly 40% of whom express little or no trust in the scientific community (Kennedy & Tyson, 2023).

Complementing overt political resistance and weaponization is the more subtle yet deeply entrenched challenge of institutional inertia (Markard et al., 2020; Munck af Rosenschöld et al., 2014; Samadi & Alipourian, 2024). Even when political will for sustainability transitions exists, large institutions - governments, corporations, multilateral bodies - are often structurally "locked in" to legacy systems shaped by decades of past decisions, investments, and routines. This path dependency phenomenon reflects the self-reinforcing nature of policies, infrastructures, and market systems that evolve to perpetuate the status quo. For instance, a city designed around automobile use cannot be transformed overnight into a walkable, transit-oriented metropolis; its existing land-use patterns, road networks, and spatial planning necessitate continued car dependence until comprehensive redesign and reinvestment occur. Likewise, global energy systems remain heavily reliant on fossil fuels, not merely due to supply-side choices, but because trillions of dollars are embedded in coal plants, oil rigs, pipelines, power grids, and vehicle fleets calibrated to carbon-intensive fuels.

Institutional structures further reinforce this inertia through standard operating procedures, performance metrics, and supply chains optimized for prevailing systems. As a result, organizational rigidity becomes the norm, which resists change and maintains operational continuity despite evolving circumstances. Transitioning from these entrenched pathways often demands far more than top-down directives. It requires retraining personnel, reconfiguring production systems, revising regulations, and shifting internal cultures - steps that entail significant upfront costs, perceived risks, and bureaucratic friction.

While exogenous shocks - such as natural disasters or economic crises - can occasionally catalyze institutional reforms that were previously deemed unthinkable (Johnstone & Schot, 2023), relying on such disruptions is neither desirable nor reliable. Instead, deliberate and proactive strategies are needed. These include institutional reforms, capacity-building initiatives, and pilot programs that foster experimentation with alternative models prior to large-scale implementation. Equally critical is strong leadership combined with strategic management to mitigate resistance, alleviate uncertainty, and demonstrate that complex transitions, while difficult, are both achievable and potentially beneficial. Through sustained pressure, visionary planning, and example-setting by pioneering organizations, the gradual transformation of societal and institutional values, metrics, and incentive structures will become feasible.

The development of the eco-surplus demands significant investment - not only in tangible resources like infrastructure and technology but also in intangible assets such as information, policymaking, and the opportunity costs incurred in the pursuit of effective solutions (Vuong & Nguyen, 2024a). Although this cultural shift may temporarily constrain or even undermine short-term socio-economic growth, the long-term benefits of fostering an eco-surplus culture justify the trade-off. The transition will be gradual, requiring persistent effort to overcome resistance from entrenched value systems and to ensure internal coherence and resilience in the emerging paradigm. This internal consistency is essential for enabling societies, institutions, and businesses to move toward truly sustainable practices.

However, cultural transformation is inherently non-linear and imperfect. It must not be rushed or forced. Instead, it should be informed by rigorous science, empirical evidence, verification mechanisms, and cross-sectoral collaboration. Enhanced focus on the social sciences and humanities - especially research addressing climate change denialism, obstruction of climate action, anthropocentric mindsets, and the evolving human-nature relationship - will be vital in enabling this transition (Abson et al., 2017; Roberts et al., 2024; Vuong & Nguyen, 2025). Equally important is the preservation of public trust in science. Taxpayers are justified in questioning the value of their financial contributions to research, and the scientific community must therefore demonstrate science's relevance and societal benefits to the public. Without such accountability, science risks being delegitimized and politically undermined (Vuong, 2018). As Nobel laureate Frances Arnold observed, "instead of viewing science as the foundation of prosperity, as an investment in the future, it [science] is being portrayed as a burden on taxpayers." Consequently, the scientific community is "paying the price," as exemplified by the substantial cuts in federal funding for science enacted during the Trump administration (Grove, 2025).

Climate change and environmental degradation are inherently global challenges. As such, environmental agendas cannot be effectively realized without both global consensus and local cooperation, which are unattainable without a foundation of mutual trust among nations, institutions, and stakeholders. These dual forces are essential for reducing systemic entropy in governance and social systems, creating the informational and institutional coherence necessary for the efficient mobilization of resources. In contrast, war represents the most extreme form of conflict, wherein parties aim to eliminate competing systems of information, values, and governance from the broader operational fabric of humanity. When the immediate survival of one's self, family, ethnicity, or nation is under existential threat, long-term ecological considerations are inevitably deprioritized. In such contexts, the formation of eco-surplus values - which require a stable, forward-looking cultural framework - becomes virtually impossible.

War also results in the violent depletion of vitality and resources that, in the face of global ecological crises, should instead be harnessed for planetary resilience. These finite resources - financial, human, environmental, and technological - are tragically redirected toward mutual destruction rather than mutual survival. Moreover, armed conflicts exacerbate the destruction of already fragile ecosystems. Examples include the deforestation and habitat loss from the Vietnam War's defoliants, the oil spills and fires in the Gulf War, or the extensive carbon emissions and landscape degradation resulting from ongoing wars in the Middle East and Eastern Europe. These impacts not only accelerate environmental crises but also compound their severity across regional and global scales. Regardless of the ideological or moral justifications for warfare, attempts to resolve conflicts through destructive means constitute profound sins against the Mother Earth's ecosystems and the future generations whose survival depends on them, including the very populations the combatants claim to protect (Vuong, Nguyen, & La, 2024).

The aftermath of war extends far beyond depleted resources and ecological devastation. It includes entrenched hatred, traumatic memories of loss, and deep-seated distrust - factors that critically hinder the possibility of future global consensus and local cooperation for addressing environmental degradation and climate change. Deteriorating ecological conditions and weakened ecosystem services, in turn, exacerbate societal stresses and deteriorate living conditions, increasing the risk of further human conflict in a destructive feedback loop.

Without a sincere commitment to nurturing the natural environments that support all life, including humanity, technological innovation and scientific advancement alone cannot deliver lasting well-being. Therefore, reducing armed conflict and promoting peaceful resolution are not only ethical imperatives—they are strategic necessities for preventing the weaponization of nature and ensuring the survival of humanity and the biosphere (Vuong, Nguyen, & La, 2024). The meaning of peace must evolve beyond its traditional conception as merely the absence of human conflict. It must encompass a broader peace between humans and nature, between the organic and inorganic systems that constitute Earth's biosphere. Only through this expanded vision of peace can humanity ensure the sustainability of both the planet and its future.

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