

# **RegenROI as a Pre-Scaling Causal Decision Framework for Climate Restoration Interventions: Integrating Complex-Adaptive Enterprise Architecture (RegenERP) and Applied Use Cases**

## **1. Introduction: The Macroeconomic Imperative for Regenerative Architecture**

The contemporary global economic architecture is undergoing a foundational paradigm shift, transitioning from linear, extractive models of value creation toward systems that prioritize holistic, systemic restoration. For decades, the dominant economic frameworks have optimized for financial extraction, often treating ecological degradation, biodiversity loss, and social inequity as exogenous externalities rather than fundamental liabilities. As the planetary climate system moves irrevocably beyond the boundaries of historically recorded human experience, traditional corporate sustainability paradigms—which largely focus on harm reduction, emissions mitigation, and net-zero carbon targets—are increasingly recognized as scientifically and economically insufficient. Sustainability, understood merely as mitigating harm, acts only as a temporary stabilization mechanism for a fundamentally destructive global ecosystem. The modern macroeconomic imperative is no longer simply to sustain a degraded environmental baseline, but to actively regenerate the ecological and social capital upon which all long-term economic stability and corporate viability depend.

This theoretical evolution demands a corresponding revolution in how enterprises, governments, and institutional investors calculate value, forecast outcomes, and engineer their internal organizational architectures. It requires the integration of climate change mitigation and adaptation policies—a concept frequently referred to as Climate Policy Integration (CPI)—to harmonize environmental interventions that are too frequently treated in isolation by fragmented funding and policy bodies. To achieve this integration and drive capital toward genuinely restorative outcomes, decision-makers require advanced analytical frameworks capable of moving beyond associative data analytics and predictive correlations to true causal reasoning. They need mathematically rigorous methodologies that can simulate the counterfactual impacts of an intervention before massive capital is deployed at scale.

This comprehensive working paper presents a detailed exploration of *RegenROI* (Regenerative Return on Investment) as a pre-scaling causal decision framework, designed to operate within the advanced

simulation environment of *RegenERP* (Regenerative Enterprise Resource Planning). By integrating the thermodynamic and biological principles of Complex Adaptive Systems (CAS) with robust Enterprise Architecture (EA) standards—specifically leveraging the TOGAF® 10th Edition framework—organizations can unbundle rigid, brittle corporate structures into highly adaptable and regenerative ecosystems. Through a mathematically rigorous, causally sound, and use-case-driven approach, this report demonstrates how forward-thinking enterprises can operationalize the principles of regenerative capitalism, evaluate climate restoration interventions on an ex-ante basis, and fundamentally redesign their value-creation mechanisms to achieve lasting symbiosis with planetary boundaries.

## **2. Theoretical Foundations: From Extractive Sustainability to Regenerative Economics**

To successfully operationalize a quantitative framework like RegenROI, it is necessary to first establish the epistemological and economic theories that distinguish "regeneration" from mere "sustainability." This distinction is not merely semantic; it dictates entirely different mathematical optimizations, strategic orientations, and structural architectural designs within a modern enterprise.

### **2.1 Regenerative Capitalism and the Net-Positive Mandate**

The concept of Regenerative Capitalism, formally synthesized and popularized by Fullerton (2015), posits that universal principles and patterns of systemic health observed in the natural world can and must be applied to macroeconomic and financial systems.<sup>1</sup> Fullerton (2015) argues that human economies are fundamentally embedded within, rather than separate from, the biosphere, and therefore human financial architectures must mimic the resilience, circularity, and regenerative capacity of living systems, ranging from cellular biology to vast global ecosystems.<sup>1</sup>

Regenerative capitalism demands a profound mindset shift from doing "less harm"—such as striving for mere carbon neutrality or incremental waste reduction—to doing "more good," commonly framed as becoming climate positive and nature positive.<sup>3</sup> This involves active, measurable restoration: rebuilding fertile topsoil, replenishing clean air and water aquifers, and actively empowering historically underserved human communities to foster inclusive collaboration and shared prosperity.<sup>3</sup> In this emergent paradigm, financial profit is not the ultimate, solitary purpose of the enterprise, but rather a natural, sustaining byproduct of systemic health and positive ecological impact.<sup>6</sup> This requires transitioning away from linear industrial models of "take-make-dispose" toward circular design innovations rooted in green chemistry, biodegradable materials, and biomimicry.<sup>4</sup> Enterprises must construct business models that are inherently restorative and constructive, favoring true multidimensional value creation over unilateral financial value extraction.<sup>4</sup>

### **2.2 Doughnut Economics: Operating within Social and Planetary Boundaries**

Complementing the principles of regenerative capitalism is the groundbreaking framework of Doughnut Economics, articulated exhaustively by Raworth (2017).<sup>8</sup> Raworth (2017) systematically deconstructs the outdated character of *Homo economicus* or "rational economic man," alongside the academic obsession

with mechanical market equilibrium, proposing instead a dynamic, complex-systems approach to human prosperity that respects the inherent limits of the Earth system.<sup>9</sup>

The "Doughnut" represents a dual-boundary compass for twenty-first-century societal progress. The inner boundary of the Doughnut constitutes the *social foundation*, comprising twelve distinct dimensions derived directly from the internationally agreed-upon United Nations Sustainable Development Goals (SDGs) of 2015, including food, housing, healthcare, gender equity, and political voice.<sup>11</sup> Falling below this foundation results in severe human deprivation. The outer boundary represents the *environmental ceiling*, consisting of nine planetary boundaries identified by Earth-system scientists, such as climate change, biodiversity loss, ocean acidification, and land-use change.<sup>11</sup> Overshooting this environmental ceiling leads to unacceptable ecological degradation and the triggering of catastrophic, irreversible Earth-system tipping points.

The explicit goal of regenerative economics is to engineer enterprises and economic policies that operate entirely within the "safe and just space" between these two boundaries, creating business models that are fundamentally distributive and regenerative by design.<sup>10</sup> However, translating these macroeconomic theories into microeconomic, firm-level corporate action requires immense precision in measurement. Traditional financial metrics utterly fail to capture ecological restoration and community well-being, rendering regenerative efforts functionally invisible to legacy decision-making systems and corporate boards.<sup>12</sup> This glaring measurement gap necessitates the introduction of advanced causal inference methodologies and multi-capital accounting frameworks to properly attribute impact and direct investment.

### **3. The Epistemology of Causal Inference in Environmental Systems**

The fundamental challenge in scaling climate restoration interventions lies in the scientific burden of attribution: how can an organization or government definitively prove that a specific policy, investment, or architectural change *caused* a specific ecological or social outcome? Current machine learning systems and predictive analytics predominantly rely on correlations and historical data associations, which are fundamentally inadequate for strategic decision-making in novel and rapidly changing environmental conditions.<sup>13</sup>

#### **3.1 The Severe Limitations of Correlational Analytics**

In environmental management, enterprise strategy, and climate policy evaluation, confusing statistical correlation with biological or economic causation can lead to catastrophic capital misallocation and systemic collapse. For example, a purely correlational machine learning model might identify that increased corporate spending on community health initiatives is strongly associated with higher local biodiversity over a five-year period. However, without establishing a rigorous causal mechanism, it is impossible to know if the corporate spending actually *caused* the biodiversity increase, if a hidden confounding variable (such as a broader regional economic boom or a shift in local weather patterns)

caused both, or if the statistical relationship is entirely spurious.<sup>15</sup>

Furthermore, traditional predictive machine learning models are anchored by the fundamental assumption that the data distribution observed during the training phase will remain stable and representative during the production or testing phase.<sup>14</sup> Climate change, by definition, introduces unprecedented, non-stationary shifts into environmental and economic systems, rendering historical correlations highly unreliable and potentially dangerous.<sup>17</sup> To generate and accurately evaluate alternative strategic actions, corporate managers and policymakers must understand the underlying structural causal mechanisms of the ecosystem, rather than relying on brittle associative predictions.<sup>13</sup>

## 3.2 Structural Causal Modeling and Pearl's Paradigm

To navigate this immense systemic complexity, the RegenROI framework relies heavily on the formal scientific discipline of causal inference, pioneered extensively by Pearl (2009).<sup>18</sup> Pearl (2009) established a rigorous mathematical language for causality, allowing researchers to move definitively beyond traditional associational statistics into the realm of Structural Causal Models (SCMs) and Directed Acyclic Graphs (DAGs).<sup>15</sup>

Causal inference in the context of complex environmental systems involves several critical methodological steps:

1. **Theoretical Foundation and Causal Discovery:** Building explicit causal graphs (DAGs) from observational data and domain expertise to map the entirety of an ecosystem's structure, identifying known confounders, colliders, and mediating variables.<sup>13</sup>
2. **Causal Effect Estimation:** Quantifying the exact statistical impact of performing an intervention (the treatment) on a given variable (the outcome), mathematically isolating and controlling for confounding variables to solve the fundamental problem of unobserved counterfactuals.<sup>13</sup>
3. **Counterfactual Simulation and Robustness Checks:** Answering complex "what if" questions using data (e.g., "What would the exact soil carbon levels have been in this specific hectare if the enterprise had *not* implemented regenerative agriculture practices?"), followed by evaluating the results against rigorous statistical assumptions.<sup>15</sup>

In modern environmental science, experimental approaches such as Randomized Controlled Trials (RCTs) are often unethical, impractical, or impossible to conduct on a planetary or macroeconomic scale.<sup>16</sup>

Therefore, analysts must rely on advanced observational causal inference methodologies. By utilizing sophisticated causal machine learning approaches such as Bayesian Additive Regression Trees (BART), Causal Forests (CF), and Double Machine Learning (DML), organizations can flexibly capture highly non-linear relationships and treatment heterogeneities.<sup>18</sup> These advanced algorithms reveal that while an *average* treatment effect across an intervention might yield a specific result, the actual impact on individual, localized micro-environments may vary significantly, allowing for hyper-targeted regenerative deployments.<sup>18</sup>

## 4. Ex-Ante Evaluation and Climate Policy Integration (CPI)

In the critical context of climate adaptation and mitigation, ecological interventions are highly complex, capital-intensive, and frequently irreversible. Therefore, structural causal models must be utilized for *ex-ante* (before the event) evaluation rather than merely *ex-post* (after the event) reporting. Ex-ante evaluation seeks to predict the precise causal effects of a program, regulation, or strategic corporate pivot on specific outcomes of interest long before capital is heavily deployed or ground is broken.<sup>22</sup>

While ex-post evaluations remain undeniably critical for verifying sustained adaptation outcomes, ensuring that interventions remain scientifically relevant in evolving environmental conditions, and documenting the precision of estimated associations<sup>24</sup>, they suffer from the fundamental economic disadvantage of occurring after resources have already been consumed. A pre-scaling causal decision framework utilizes ex-ante causal simulations to map operational tradeoffs, formulate a wide range of alternative management strategies, and mathematically assess the plausibility of meeting current and future objectives under drastically different future climate scenarios.<sup>26</sup>

This is particularly critical for Climate Policy Integration (CPI). Historically, climate mitigation strategies (reducing greenhouse gas emissions) and climate adaptation strategies (preparing communities and infrastructure for unavoidable climate impacts) have been developed entirely separately, with the two processes treated in deep isolation by fragmented funding bodies.<sup>27</sup> This fragmentation is evident in use cases such as the response to the unprecedented extreme heatwaves that occurred in the UK during the summer of 2022.<sup>27</sup> Practitioners realized that integrating adaptation and mitigation was crucial, yet such integration was rarely implemented in practice due to a lack of coherent decision-making frameworks.<sup>27</sup> The predictive, unified capability of ex-ante causal inference forms the functional, scientific basis of the RegenERP simulation environment, allowing for true CPI at the enterprise level.

## 5. The RegenROI Framework: Mathematical and Conceptual Architecture

To accurately quantify and incentivize regenerative value creation, organizations must definitively move beyond the traditional Return on Investment (ROI) metric, which captures only financial capital extraction and ignores planetary boundaries. The RegenROI framework is a multidimensional, multi-capital accounting protocol specifically designed to capture ecological restoration, community resilience, and economic viability simultaneously, integrating the stringent double materiality requirements established by modern regulatory standards such as the European Union's Corporate Sustainability Reporting Directive (CSRD).<sup>28</sup>

The core mathematical formula driving the RegenROI framework is defined as follows:

$$RegenROI = \frac{S \cdot A}{I \cdot R}$$

This complex equation explicitly balances multiple forms of capital while introducing powerful systemic modifiers for ecological symbiosis and organizational adaptability.

## 5.1 Component Breakdown and Variable Definitions

The variables embedded within the RegenROI equation represent a comprehensive, scientifically grounded synthesis of human, ecological, and financial dynamics, allowing for seamless multi-capital accounting.

The following table provides a detailed exposition of each variable within the causal framework:

<b>Variable</b>	<b>Definition</b>	<b>Conceptual Function and Theoretical Alignment</b>
<b>Pp</b>	<b>People Impact</b>	Measures quantifiable social value creation. Aligns directly with Raworth's (2017) social foundation. <sup>9</sup> Captures metrics such as community empowerment, equitable resource access, localized health improvements, and labor rights. <sup>5</sup>
<b>Pl</b>	<b>Planet Impact</b>	Measures quantifiable ecological restoration. Aligns directly with maintaining and restoring planetary boundaries. <sup>11</sup> Captures metrics such as soil regeneration, net carbon drawdown, biodiversity enhancement, and circular material flow. <sup>5</sup>
<b>Pf</b>	<b>Profit Impact</b>	Measures direct and indirect financial viability. Ensures the enterprise remains economically self-sustaining, capable of continuous operation, and attractive to capital markets without relying on extraction. <sup>28</sup>

<b>W<sub>p</sub>, W<sub>l</sub>, W<sub>f</sub></b>	<b>Weights</b>	Context-specific numerical coefficients that adjust the relative strategic importance of People, Planet, and Profit based on the specific ecological or socioeconomic urgency of the localized environment. <sup>28</sup>
<b>S</b>	<b>Symbiosis Coefficient</b>	An exponential multiplier that quantifies the degree to which the intervention creates positive, self-reinforcing feedback loops with adjacent natural and social systems, rather than operating in an isolated, siloed manner. <sup>28</sup>
<b>A</b>	<b>Adaptivity Rate</b>	Represents the system's inherent capacity to learn, evolve, and maintain resilience in the face of external systemic shocks (e.g., market volatility, extreme climate events, supply chain disruptions). <sup>28</sup>
<b>I</b>	<b>Investment</b>	The total aggregate financial, temporal, and resource capital injected into the project or intervention. <sup>28</sup>
<b>R</b>	<b>Regeneration Cost Factor</b>	A critical divisor representing the collateral damage, "internal debt," or negative externalities created by the intervention that must be actively repaired (e.g., the ecological cost of extracting raw materials to manufacture green technologies). <sup>28</sup>

## 5.2 Systemic Implications of the Mathematical Modifiers

The true scientific elegance of the RegenROI formula lies in its non-linear modifiers: the Symbiosis coefficient ( $S$ ), the Adaptivity rate ( $A$ ), and the Regeneration Cost Factor ( $R$ ).

In traditional, linear financial models, an investment ( $I$ ) that yields high financial profit ( $Pf$ ) results in a high ROI, utterly regardless of the ecological destruction or social inequity caused in the process. In the RegenROI framework, the mathematics are fundamentally altered. If a corporate intervention generates high profit but causes immense collateral ecological damage, the Regeneration Cost Factor ( $R$ ) in the denominator increases sharply, proportionally driving down the overall RegenROI score to near zero. Similarly, if an intervention is highly profitable but highly brittle—lacking the systemic adaptivity to withstand imminent climate shocks—the Adaptivity rate ( $A$ ) approaches zero, thereby collapsing the numerator and rendering the investment mathematically unviable.<sup>28</sup>

Conversely, if an intervention actively works in harmony with natural biological systems—such as a regenerative agriculture project where improved soil health (Planet Impact) naturally leads to better long-term crop yields (Profit Impact) and improved farmer livelihoods (People Impact)—the Symbiosis coefficient ( $S$ ) acts as an exponential multiplier, drastically inflating the RegenROI score.<sup>5</sup> The equation scientifically forces the enterprise to internalize its externalities, making regenerative action mathematically and strategically superior to extractive action.<sup>28</sup>

## 6. Complex-Adaptive Enterprise Architecture: The Role of TOGAF 10th Edition

Calculating an accurate RegenROI requires a massive, continuous influx of diverse and highly verified data streams across an organization's entire global value chain. Legacy, siloed IT infrastructures and rigid corporate hierarchies are technologically incapable of supporting this level of systemic multi-capital accounting. To fully operationalize RegenROI, an organization must physically and digitally restructure itself from the ground up. This monumental transformation is achieved through the deployment of advanced Enterprise Architecture (EA), specifically leveraging the ubiquitous TOGAF® 10th Edition standard.<sup>31</sup>

### 6.1 The TOGAF Framework and the BDAT Architecture Layers

The TOGAF framework, developed and maintained by the global consortium known as The Open Group, is the most prominent and reliable standard for ensuring that an organization's digital and operational systems align tightly with its strategic business goals, preventing lock-in to proprietary methods.<sup>33</sup> The framework has evolved significantly since its inception in 1995 and the subsequent push for architectural standards following legislation like the US Clinger-Cohen Act of 1996.<sup>35</sup> TOGAF systematically

organizes enterprise architecture into four foundational domains, collectively known by the acronym BDAT: Business, Data, Application, and Technology.<sup>37</sup>

To build a genuinely regenerative enterprise, each of these four BDAT layers must be fundamentally re-architected:

1. **Business Architecture:** This domain defines the overarching regenerative strategy, governance structures, and organizational unbundling required for agility. It explicitly shifts the corporate purpose from mere shareholder value extraction to multi-stakeholder value creation, integrating Raworth's (2017) distributive design principles directly into the operational DNA of the firm.<sup>9</sup>
2. **Data Architecture:** This domain defines exactly what data exists across the organization, how it is structured, where it is stored, and how it moves between systems. In environments shaped by rigorous compliance mandates (like the GDPR, NIS2, or CSRD), a tightly governed data architecture ensures that the ecological and social variables ( $Pl$ ,  $Pp$ ) injected into the RegenROI formula are perfectly auditable, secure, and causally sound.<sup>29</sup>
3. **Application Architecture:** This domain describes the software landscape required to run the enterprise, including the deployment of causal AI engines, structural causal modeling tools, and the RegenERP simulation environment itself. It meticulously maps how these disparate systems interact to support regenerative business functions and where controls must be placed to ensure data integrity.<sup>13</sup>
4. **Technology Architecture:** This domain covers the physical and logical infrastructure that underpins the rest of the estate. In a regenerative context, this includes expansive IoT sensor networks embedded in agricultural fields, satellite imaging telemetry for biodiversity tracking, and highly energy-efficient cloud environments that provide the computational power required for continuous ex-ante and ex-post evaluation.<sup>15</sup>

The TOGAF 10th Edition provides an expanded, highly agile approach to this architecture, focusing strictly on universal concepts that can be dynamically configured to support rapid digital transformation and continuous organizational improvement.<sup>33</sup>

## 6.2 Transitioning to Complex Adaptive Systems (CAS) Theory

Historically, Enterprise Architecture has sometimes been criticized as a static, bureaucratic pile of obscure models that slows down innovation.<sup>39</sup> However, when integrated seamlessly with the scientific theory of Complex Adaptive Systems (CAS), EA becomes a dynamic and operational framework capable of navigating non-linear climate realities and rapidly shifting market dynamics.<sup>39</sup>

A Complex Adaptive System is fundamentally characterized by individual agents that operate in self-organizing ways, constantly adapting to changing environments through intricate feedback loops, emergence, and dynamic balance.<sup>36</sup> Applying CAS theory to the TOGAF framework transforms the modern enterprise from a rigid, top-down hierarchy into an agile, unbundled network of autonomous capabilities.<sup>30</sup>

By unbundling massive organizations into smaller, autonomous units—often referred to as micro-enterprises, a model championed by highly adaptable companies like Haier and Amazon—an organization successfully adheres to Ashby's Law of Requisite Variety. Ashby's Law dictates a fundamental truth of cybernetics: to effectively manage a complex environment, the internal complexity and adaptability of the managing system must precisely match the external complexity of the environment.<sup>30</sup> In a regenerative context, these decentralized micro-enterprises operate with their own localized RegenROI targets, finding strategic coherence with local bioregional signals and vastly reducing the systemic brittleness associated with centralized command-and-control structures.<sup>30</sup>

## 7. RegenERP: Simulating Regenerative Interventions and Embedding "Sisu"

The theoretical synthesis of Causal Inference methodologies, the RegenROI mathematical modeling framework, and Complex-Adaptive TOGAF architecture culminates in the deployment of *RegenERP* (Regenerative Enterprise Resource Planning). Developed as a core technological methodology by CISUREGEN—an initiative fusing Finnish *sisu* (resilient determination) with advanced regenerative systems intelligence—RegenERP represents a total paradigm shift in corporate planning software.<sup>28</sup>

Slated for wider release and testing between 2026-2027, RegenERP is not merely a static ledger for recording past actions and historical financial transactions; it is a forward-looking, causal simulation environment designed specifically for organizations applying regenerative concepts in value creation and strategic planning.<sup>28</sup>

### 7.1 The Pre-Scaling Causal Simulation Engine

Before a multinational enterprise commits hundreds of millions of dollars to a climate restoration intervention, it must understand the exact causal ripple effects of that decision across all BDAT layers and all planetary boundaries. RegenERP utilizes advanced structural causal models to run sophisticated ex-ante simulations.<sup>13</sup>

When a strategic planner proposes a massive intervention (e.g., shifting 50% of a global supply chain to agroforestry practices), RegenERP immediately ingests vast quantities of observational data and constructs a Directed Acyclic Graph (DAG).<sup>15</sup> The system then runs thousands of counterfactual scenarios: "If we execute this specific policy today, what is the exact estimated causal effect on Scope 3 emissions, local watershed health, and long-term commodity pricing over a ten-year horizon, compared to the baseline scenario of inaction?"<sup>15</sup>

The ultimate output of this simulation is a projected RegenROI score.<sup>28</sup> By continuously adjusting the intervention parameters in the simulation, strategic planners can algorithmically optimize the Symbiosis (  $S$  ) and Adaptivity (  $A$  ) variables, minimizing the Regeneration Cost Factor (  $R$  ) before a single dollar

of real-world capital is spent. This powerful pre-scaling capability permanently bridges the gap between high-level regenerative macroeconomic theory (like Fullerton's capitalism) and localized, pragmatic corporate execution.

## 7.2 Embedding Systemic Resilience and Finnish "Sisu"

A highly unique philosophical and algorithmic underpinning of the RegenERP environment is its deep integration of the Finnish cultural concept of *sisu*—a mindset characterized by sustained resilience, extraordinary perseverance, and unyielding determination in the face of extreme adversity and systemic shock.<sup>28</sup> In the context of global climate collapse, ecological degradation, and systemic economic transformation, superficial sustainability initiatives almost always fail when they encounter immediate, short-term financial pressure.

CISUREGEN explicitly embeds the concept of *sisu* into the algorithmic governance of RegenERP by

heavily weighting the Adaptivity ( $A$ ) variable in the RegenROI formula.<sup>28</sup> In the simulation environment, an intervention is only greenlit for real-world deployment if the causal models prove it possesses the structural integrity and adaptive capacity to withstand long-term environmental volatility, extreme weather events, and severe market fluctuations. This ensures that enterprises move beyond fleeting compliance exercises to generate lasting, resilient regenerative value.

## 8. Applied Use Cases: Pragmatic Insight into Climate Restoration

To definitively demonstrate the scientific reliability, architectural validity, and pragmatic utility of the RegenROI framework and the RegenERP simulation environment, the following sections detail three highly specific, applied use cases across distinct global economic sectors. These use cases illustrate the transition from theory to operational reality.

### 8.1 Use Case 1: Industrial Agricultural Supply Chain Transition

#### The Macroeconomic Challenge:

A multinational food and beverage corporation relies heavily on a global industrial agriculture supply chain that rapidly degrades topsoil, pollutes critical watersheds with synthetic nitrogen fertilizers, and operates on dangerously thin financial margins for local farmers. The corporation faces immense regulatory and consumer pressure to achieve net-zero emissions while simultaneously securing its fragile supply chain against climate-induced crop failures, droughts, and extreme weather events.

**The Proposed Intervention:** The company's strategic board proposes a massive transition of 100,000 hectares of farmland to regenerative agriculture practices. This includes the mandatory implementation of cover cropping, no-till farming, and a drastic reduction in synthetic inputs. Agronomic studies suggest that widespread global adoption of these exact regenerative methods could potentially sequester over

100% of human-caused carbon emissions globally.<sup>42</sup> However, the short-term financial risks to the enterprise, including potential yield drops during the transition period, are deemed unacceptably high by traditional financial analysts.

**Applying RegenERP and RegenROI:** Refusing to rely on linear ROI, the corporation models the ex-ante causal impact of the transition using RegenERP.<sup>23</sup> The TOGAF Data Architecture layer seamlessly integrates decades of historical yield data, real-time satellite telemetry on soil organic carbon, and highly granular local economic indicators into the causal engine.

- **Planet Impact (  $P_l$  ):** The causal inference engine, utilizing Difference-in-Differences (DiD) analysis, isolates the effect of the new practices and simulates a massive, verifiable increase in soil carbon sequestration and critical water retention, yielding an exceptionally high positive score.<sup>15</sup>
- **People Impact (  $P_p$  ):** The structural causal model projects significantly improved respiratory and physiological health for local farming communities (due to the causal reduction in chemical runoff and airborne particulate matter), alongside higher long-term farmer autonomy and financial stability.<sup>16</sup>
- **Profit Impact (  $P_f$  ):** The advanced simulation acknowledges a probable 10% dip in yield in years 1-2 (the transition phase), but confidently projects a 20% increase in baseline profitability by year 4 due to the elimination of expensive fertilizer costs and the attainment of premium market pricing for regenerative yields.<sup>42</sup>

The RegenERP system mathematically calculates a phenomenally high Symbiosis coefficient (  $S$  ) because the ecological restoration directly supports and amplifies long-term financial viability. The initial Investment (  $I$  ) is substantial, but because the intervention works holistically *with* natural systems, the collateral Regeneration Cost Factor (  $R$  ) is exceptionally low.<sup>5</sup> The RegenERP platform confirms a highly positive projected RegenROI, providing the boardroom with the precise, causal, mathematically sound justification required to override traditional ROI objections and approve the transition.

## 8.2 Use Case 2: Urban Infrastructure Resilience and Extreme Heat Management

**The Macroeconomic Challenge:** A major metropolitan government in the global north is facing a rapidly increasing frequency of extreme, lethal heatwaves, akin to the devastating events experienced in the UK during the summer of 2022 when temperatures shockingly exceeded 40°C for the first time on record.<sup>27</sup> Historically, urban climate policies have been deeply fragmented: mitigation (reducing emissions to prevent future heat) and adaptation (preparing citizens for current heat) have been treated as entirely siloed initiatives.<sup>27</sup> The city must urgently upgrade its infrastructure, balancing immediate public health crisis management with long-term, legally binding climate targets.

### The Proposed Intervention:

The city's planning department evaluates two competing proposals. The first is a traditional "grey"

infrastructure approach, requiring massive public investment in centralized air conditioning centers powered by natural gas peaker plants. The second is the deployment of extensive "green-blue" infrastructure, encompassing the planting of millions of urban forest canopy trees, the installation of permeable pavements, and the restoration of historical urban wetlands.

**Applying RegenERP and RegenROI:** The city deploys the RegenROI framework to objectively evaluate the integration of mitigation and adaptation (CPI).<sup>27</sup>

- **The Grey Strategy Simulation:** While providing immediate, localized heat relief (generating a moderate People Impact), the causal simulation reveals that the grey strategy dramatically increases greenhouse gas emissions (a severely negative Planet Impact). Furthermore, it creates a highly brittle urban power grid susceptible to catastrophic blackouts during peak demand (resulting in an abysmal Adaptivity score,  $(\overset{A}{\text{---}})$ ). The massive emissions also create an insurmountable collateral Regeneration Cost Factor (  $\overset{R}{\text{---}}$  ). Consequently, the projected RegenROI is deeply negative, signaling a catastrophic long-term failure.<sup>28</sup>
- **The Green-Blue Strategy Simulation:** Conversely, the simulation shows that urban forests provide excellent, decentralized localized cooling, causally reducing heat-related mortality and morbidity (high People Impact). Simultaneously, these biological assets sequester carbon and restore local biodiversity corridors (high Planet Impact). Crucially, the trees act as a decentralized cooling system that requires zero electrical grid input, resulting in exceptional Adaptivity (  $\overset{A}{\text{---}}$  ) to future energy shocks.

Through the use of advanced causal machine learning models evaluating environmental policy<sup>21</sup>, the ex-ante evaluation irrefutably proves that the green-blue infrastructure generates a compounding, highly positive RegenROI. The TOGAF application and technology layers are subsequently utilized to track the physical deployment of these biological assets via IoT sensors, ensuring that city planners possess continuous data feedback loops to adjust to the complex adaptive nature of the evolving urban ecosystem.<sup>37</sup>

### 8.3 Use Case 3: Ecosystem Restoration and Manufacturing Circularity

**The Macroeconomic Challenge:** A global technology hardware manufacturer is seeking to move aggressively beyond mere environmental compliance to establish a truly regenerative, industry-leading business model. Their current, highly linear manufacturing process relies heavily on extracting rare earth metals from vulnerable regions, generating highly toxic ecological waste that devastates both human health and delicate downstream aquatic ecosystems.<sup>5</sup> The company is facing immense pressure from institutional investors demanding compliance with the EU's Corporate Sustainability Reporting Directive (CSRD).

**The Proposed Intervention:** The hardware manufacturer plans to radically redesign its entire product

line using non-toxic, biodegradable, and infinitely recyclable materials (circular design). Furthermore, the company commits to actively investing a significant portion of its gross revenue into restoring the specific highland ecosystems previously degraded by their historical mining operations, drawing inspiration from successful community-invested highland restoration projects in regions like Tigray, Ethiopia.<sup>5</sup>

**Applying RegenERP and RegenROI:** This complex use case relies heavily on proving the double materiality mandated by the CSRD, captured perfectly by multi-capital accounting principles.<sup>29</sup>

- Through the TOGAF Business and Technology architectures, the massive corporation unbundles its monolithic operations into agile micro-enterprises, assigning specific, highly autonomous teams to manage the circular recovery of specific materials.<sup>30</sup>
- The causal inference engine within RegenERP is tasked with the highly complex epidemiological job of disentangling the specific health outcomes of human communities living near the restoration sites from general regional socioeconomic trends. Using Double Machine Learning (DML), the framework ensures that the company's financial investment is genuinely causing the positive People Impact ( $P_p$ ), rather than simply correlating with an influx of general foreign aid.<sup>15</sup>
- The RegenROI equation heavily scrutinizes the Regeneration Cost Factor ( $R$ ). In the company's past linear model,  $R$  was overwhelmingly massive due to the devastating collateral toxicity of the rare earth mining. By shifting entirely to circular materials,  $R$  is driven down mathematically to near zero.

The resulting, highly audited RegenROI metric serves as an integrated, board-level dashboard for complete business model transformation. It proves definitively to institutional investors and regulators that the company has successfully and fundamentally decoupled financial value creation from ecological destruction.<sup>29</sup>

## 9. Implementation Pathways and Strategic Recommendations

For global enterprises and government bodies to successfully adopt RegenROI and RegenERP as functional pre-scaling causal decision frameworks, a highly structured, rigorous implementation pathway is strictly required. The transition from legacy extractive financial metrics to advanced regenerative multi-capital accounting cannot be achieved through superficial software patches or marketing campaigns; it requires deep, systemic architectural transformation.

### 9.1 Algorithmic Governance and the Mindset Shift

First and foremost, organizational leadership must universally adopt an adaptation and regeneration mindset at the highest levels of governance.<sup>7</sup> This requires acknowledging a fundamental truth of regenerative capitalism: financial profit is the necessary result of systemic health, not its primary, isolating purpose.<sup>6</sup> Executive boards must integrate RegenROI into their core fiduciary duties and

compensation structures, systematically replacing legacy hurdle rates and linear ROI requirements that have historically incentivized ecological exploitation and short-termism. This transition aligns closely with the core principles of stakeholder capitalism and the global B-Corp movement, permanently shifting the corporate mandate from shareholder primacy to biological and social symbiosis.<sup>30</sup>

## 9.2 Enterprise Architectural Maturation

Organizations must immediately conduct a comprehensive baseline audit using the TOGAF 10th Edition framework to accurately assess their current BDAT (Business, Data, Application, Technology) maturity.<sup>31</sup>

- The **Business** architectural layer must be fundamentally reconfigured to support localized, bioregional decision-making, allowing internal micro-enterprises to respond organically and autonomously to real-world environmental signals, adhering strictly to Ashby's Law of Requisite Variety.<sup>30</sup>
- The **Data** architectural layer must be radically upgraded and secured to ingest vast arrays of unstructured, multi-capital data, ranging from raw satellite imagery and soil moisture sensors to anonymized epidemiological health records and supply chain logistics.<sup>15</sup>
- The **Application and Technology** architectural layers must be provisioned with immense computational resources to support heavily demanding causal machine learning algorithms, moving entirely away from simple predictive analytics and basic A/B testing.<sup>13</sup>

## 9.3 Enforcing Methodological Rigor in Causal Inference

Finally, enterprises must establish an uncompromising culture of rigorous scientific evaluation. As established firmly by Pearl (2009), data alone is fundamentally dumb; it requires a theoretical, structural model to yield objective causal truth.<sup>18</sup> Organizations should legally or procedurally mandate that no major climate restoration intervention or supply chain pivot is funded without an accompanying ex-ante causal simulation. This must include a formalized Directed Acyclic Graph (DAG) proving the precise pathway to impact, alongside a highly formalized plan for continuous ex-post observational robustness checks to verify the ongoing accuracy of the simulation.<sup>15</sup> By strictly adhering to these epidemiological and economic standards of causality, enterprises protect themselves against the severe legal and reputational risks associated with "greenwashing" while ensuring that their deployed capital achieves genuine, measurable restorative effects.<sup>24</sup>

## 10. Conclusion

The escalating, existential threat of planetary boundary overshoot necessitates an immediate and uncompromising departure from linear economic models and reductive, harm-mitigation sustainability metrics. As demonstrated exhaustively through the theoretical synthesis of regenerative capitalism, Doughnut Economics, and advanced causal inference methodologies, the RegenROI formula provides a mathematically rigorous, multi-capital framework for evaluating and incentivizing true systemic value creation. When this mathematical framework is successfully operationalized within the Complex Adaptive Systems architecture of the TOGAF 10th Edition standard, and subsequently executed through

the computational causal simulation environment of RegenERP, global organizations are equipped with a profoundly powerful pre-scaling tool. By shifting decisively from brittle correlational guesswork to robust causal certainty, forward-thinking enterprises and governments can confidently design, simulate, and execute immense climate restoration interventions. In doing so, they ensure the symbiotic, highly adaptive flourishing of people, planet, and profit for generations to come, redefining the very nature of economic progress in the twenty-first century.

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